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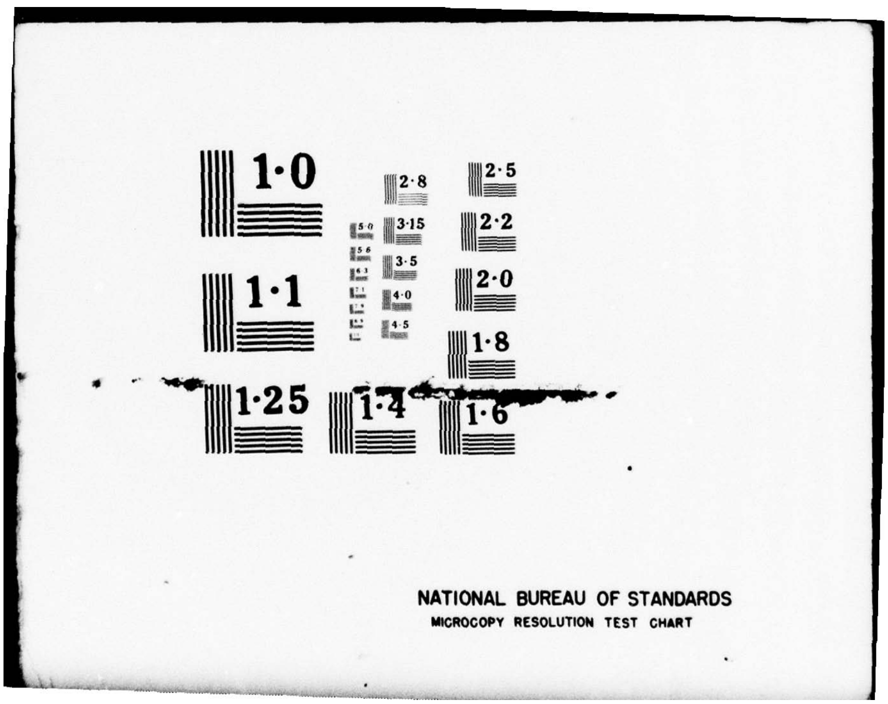
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FOREWORD

The Quarterly Bulletin is designed primarily for the information of Canadian industry, universities, and government departments and agencies. It provides a regular review of the interests and current activities of two Divisions of the National Research Council Canada:

Division of Mechanical Engineering
National Aeronautical Establishment

Some of the work of the two Divisions comprises classified projects that may not be freely reported and contractual projects of limited general interest. Other work, not generally reported herein, includes calibrations, routine analyses and the testing of proprietary products.

Comments or enquiries relating to any matter published in this Bulletin should be addressed to: *DME/NAE Bulletin, National Research Council Canada, Ottawa, Ontario, K1A 0R6*, mentioning the number of the Bulletin.

AVANT-PROPOS

Le Bulletin trimestriel est conçu en premier lieu pour l'information de l'industrie Canadienne, des universités, des agences et des départements gouvernementaux. Il fournit une revue régulière des intérêts et des activités actuelles auxquels se consacrent deux Divisions du Conseil national de recherches Canada:

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Quelques uns des travaux des deux Divisions comprennent des projets classifiés qu'on ne peut pas rapporter librement et des projets contractuels d'un intérêt général limité. D'autres travaux, non rapportés ci-après dans l'ensemble, incluent des étalonnages, des analyses de routine, et l'essai de produits de spécialité.

Veuillez adresser tout commentaire et toute question ayant rapport à un sujet quelconque publié dans ce Bulletin à: *DME/NAE Bulletin, Conseil national de recherches Canada, Ottawa, Ontario, K1A 0R6*, en faisant mention du numéro du Bulletin.

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TURBULENT CHARACTERISTICS OF SOME CANADIAN CUMULUS CLOUDS

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ABSTRACT

The turbulent characteristics of 17 Canadian cumulus clouds have been documented using the measurements from a specially instrumented T-33 aircraft. Most of the 33 cloud penetrations were made through the tops of cumuli 1-4.5 km in depth. Turbulent energy spectra over a range of wavelengths from 15 to 2500 m have been obtained for the two horizontal and the vertical gust velocities. Mean flow characteristics, especially any expected updrafts, tended to be obscured by turbulent fluctuations. The modal root-mean-square gust velocity was 1.7 m s^{-1} and the calculated modal turbulent energy dissipation was 160 cm^2 s^{-3}. Based on measured accelerations, estimates were made of expected vertical forces on several aircraft with a wide range of wing loadings. Cumulus clouds similar to those studied do not pose a safety hazard to these aircraft, and crew and passengers can easily tolerate the turbulence levels.

1.0 INTRODUCTION

There have been only a few observational studies which have measured the turbulent characteristics of cumulus clouds. MacCready (1964) and Ackerman (1967, 1968) summarize these studies. During 1974 and 1975 an attempt was made to document as many turbulent parameters as possible in Canadian cumulus; a summary has been prepared for this paper. The data were collected as part of a weather modification research program designed to examine the feasibility of stimulating rain to fall from cumulus clouds onto forest fires (Isaac et al., 1975). A seeding plan has been developed which involves burning pyrotechnic flares attached to an aircraft flying through the cloud near its top. In order to establish the safety factor in flying within such clouds and in order to measure and calculate the dispersion rate of seeding material placed into the cloud, it was necessary to measure in-cloud turbulence levels.

Turbulence encountered in cumulus clouds can affect aircraft performance. For example, MacCready (1964) states that cumuli are in the "heavy" region of his turbulence intensity scale and this could produce a moderate-heavy response in a slow flying aircraft (<200 mph) but a heavy-extreme response in a fast flying aircraft (>400 mph). Many papers, such as those by Houbolt (1973) and Hacklinger (1973), discuss the importance of knowing atmospheric turbulence levels for aircraft design. Since most commercial and military aircraft occasionally have to fly through small cumulus clouds and since the number of meteorological aircraft studying clouds is increasing, it is important to document turbulence intensities in cumulus clouds.

In order to understand, model and perhaps artificially modify cumulus clouds, it is important to know the magnitude of the turbulent fluctuations inside them. For example, Kyle (1974), Summers et al. (1972) and Todd (1965) attempted to model the rate of dispersion of seeding material within a cloud. The important parameter used in their calculations was the dissipation rate of turbulent energy. Recently Cotton (1975) discussed the importance and difficulty of modeling turbulent transport mechanisms in cumulus clouds.

The equipment used and the turbulence data collected by studying 33 runs through 17 cumulus clouds are described in this paper. The emphasis in the program to date has been on cloud-top measurements. However, some measurements in-cloud at cloud base, under cloud base and in precipitation

at cloud base have also been collected. An attempt will be made to present general conclusions on cumulus cloud turbulence properties. The aircraft has the capability of documenting the mean flow dynamics of cumulus clouds and illustrations of this will be given. However, at the moment no precise picture has emerged and future experiments are required to better document mean flow characteristics.

2.0 AIRCRAFT AND INSTRUMENTATION

The data reported below were measured by the T-33 atmospheric research aircraft (Fig. 1) operated by the Flight Research Laboratory of the National Aeronautical Establishment (NAE), a division of the National Research Council of Canada. It was originally instrumented for turbulence research 15 years ago, and has undergone continual instrumentation refinement since that time. It has been used in a number of national and international atmospheric research programs, including the Colorado Lee Wave Experiment, Roughrider, Haven Hop and the International Field Year on the Great Lakes (Mather, 1967; McBean and MacPherson, 1976). It has measured turbulence generated by a variety of natural sources (boundary layer, thunderstorms, waves, shear associated with the jet stream) and has probed the vortex wakes of jet transports (Caiger and Gould, 1970; Gould and MacPherson, 1972, 1973; Mather, 1968; Mather and Treddenick, 1969; Treddenick, 1970, 1971). During the international programs, data measured by the T-33 have been intercompared with similar measurements by other atmospheric research aircraft, including two RB-57F's of the USAF Air Weather Service, an RAE VC-10, and the NCAR Sabreliner and Buffalo (MacPherson, 1974).

The aircraft is fully equipped for all-weather operations, with dual VHF, VOR-ILS, ADF and transponder. Recently a GNS-500A area navigation system has been installed, which continously outputs latitude and longitude and a number of other related parameters such as track deviation, time and distance to waypoints, ground speed, etc. In the current weather modification experiment the T-33 serves as the seeding aircraft. Flare pods for dispensing silver iodide have been developed and are mounted under the wings.

The T-33 instrumentation is capable of measuring the three orthogonal components of atmospheric motion along the longitudinal, lateral and vertical axes of the aircraft in terms of the true gust velocities. This provides a description of the air motion independent of the characteristics of the aircraft over a range of wavelengths from 15 to 2500 m for an aircraft speed of 250 kt (130 m s^{-1}). Primary air motion sensors are the angle of attack and sideslip vanes mounted on a boom on the aircraft nose, and a differential total pressure transducer attached to a pitot probe on the lower surface of the aircraft nose. Measurement of the three-axis accelerations, angles and angular rates allow for calculation of the transient inertial velocities along the three axes and, when combined with outputs from the primary air motion sensors, the true gust velocities are obtained. These are then resolved into earth-fixed axes aligned with the mean wind direction, as computed from the measured true airspeed, heading, and Doppler-measured ground speed and drift angle. Signals from two de-iced Rosemount total temperature probes are corrected for dynamic heating to give absolute static temperature and sensitive fast-response (0.1 s time constant) temperature fluctuations. Humidity measurements are provided by a Cambridge dewpoint sensor and a Lyman-alpha humidiometer.

To prevent aliasing, all data are passed through fourth-order Butterworth filters down 3 dB at 10 Hz. Up to 30 parameters are digitized and recorded in serial-digital format at a rate of 32 samples per second per parameter. True gust velocities, fluxes, winds, etc., are computed by standard methods, the details of which are given by MacPherson (1973). During the analysis, the gust velocity time histories are high-pass filtered at 0.05 Hz, giving a wavelength limit of approximately 2500 m at the typical operating speeds of the T-33. Root-mean-square (rms) values are computed for each gust component from the filtered time histories.

A direct measurement of the rate of viscous dissipation of turbulent energy cannot be made on the T-33, for the viscous dissipation occurs at frequencies greater than the capabilities of the T-33 gust measuring system. Kolmogorov's similarity hypothesis, however, presents a picture of turbulence for which it is assumed that turbulence enters the steady system at large eddy sizes, and the eddy

energy "flows" from the larger to the smaller eddies and leaves the system through viscous heating. The Kolmogorov law may be written as $\Phi(k) = \alpha\epsilon^{2/3} k^{-5/3}$, where $\Phi(k)$ is the power spectral density, k is wavenumber, α is a constant for the inertial subrange and ϵ is the rate at which energy is dissipated in the cascade of energy from larger to smaller eddy sizes in the inertial subrange. For most of the measured turbulence data the $-5/3$ power law appears to be representative for wavelengths <70 m, so dissipation rates can be computed by integrating both sides of the above expression over a portion of the inertial subrange, 0.015 to 0.05 m^{-1}, eg.,

$$\epsilon^{2/3} = \int_{0.015}^{0.05} \Phi(k)dk/\alpha \int_{0.015}^{0.05} k^{-5/3}dk = \frac{0.073}{\alpha} \int_{0.015}^{0.05} \Phi(k)dk, \tag{1}$$

where the integral is the turbulent kinetic energy ($m^2\ s^{-2}$) in the range of wavelengths from 20 to 67 m. For the longitudinal and transverse spectra, α is set equal to 0.16 and 0.21, respectively (Ackerman, 1968).

3.0 DATA

Results of 33 turbulence runs through the 17 selected clouds are given in Table 1. The data were collected as part of a weather modification experiment in which the seeding technique was to burn wing-mounted AgI pyrotechnic flares fixed to an aircraft flying through cumuli at the -5 to -10°C level. An attempt was made to examine most clouds within this temperature range or near cloud top. For the 26 cloud-top runs, the modal penetration level was -5°C with 15 of the 17 clouds having been penetrated between 0°C and -10°C. The cloud depth was between 1 and 4.5 km for 16 of the 17 clouds, the one exception being 600 m deep. Clouds 2 and 3 were also examined within the cloud at the base. Runs were made underneath or at the cloud base for clouds 5, 8 and 11 and for the latter two the runs were made through precipitation. Three of the clouds (1, 2 and 8) were sitting over forest fires. Clouds 6, 7, 8, 9, 11 and 12 were seeded with AgI. In some cases, as noted in column 7, more than one cloud element was penetrated on a single run, although these were usually part of the same cloud.

All flights were flown between mid-July and the end of August. Clouds 1 and 5 were penetrated in the summer of 1974 in order to determine the characteristic of unseeded cumulus clouds. Cloud 1, penetrated in Flight 7, was actively building over a very large forest fire in the Red Lake area of northwestern Ontario. Flight 8 was flown in the same area later that day after clouds had begun to dissipate. Flights 10 and 11 (1974) and Flight 25 (1975) were flown through towering cumulus clouds over the Gatineau Hills north of Ottawa. The remaining flights (16-24) were flown in a cloud seeding experiment conducted in the Yellowknife area during July 1975. Cloud penetrations were made in pairs whenever possible, one in a crosswind direction for a simulated or actual seeding run and one parallel to the wind direction.

For each run, rms true gust velocities are listed for the three components of turbulence, both in-cloud and out-of-cloud. Gusts have been resolved into earth-fixed axes, with the u component aligned with the mean wind direction, the lateral v component at right angles to it and the w component representing the vertical gust. Turbulent energy dissipation rates were computed from the longitudinal gust component in aircraft axes using the method outlined above.

Spectra for the three components of true gust velocity in earth-fixed axes are presented in Figure 2 for six of the runs. Only data for the time within cloud (listed on figure) are used to produce these spectra. In the final stage of computation, the spectra are smoothed by averaging the individual spectral densities over equal logarithmic frequency intervals. The length of time within cloud has two effects on these presentations, i.e., more data give a wider wavelength range and smoother spectra. The spectrum of each gust component has been normalized by the square of the listed rms value of that component. The scale length L listed for each component was computed by matching the integral of

each spectrum to the appropriate von Kármán spectrum integrated over the same frequency range, 0.01 to 0.05 m^{-1}.

The spectra averaged for all cloud-top penetrations are shown in Figure 3(a) for the three orthogonal components of turbulence within cloud. The longitudinal and lateral components fit the −5/3 power law at wavelengths up to about 400 m, whereas the spectrum for the vertical component deviates with a steeper slope at wavelengths between 70 and 400 m. Figure 3(b) compares the average in-cloud vertical gust spectrum with that for immediately out-of-cloud, and shows that the increased energy in the 70-400 m range is peculiar to the vertical gust spectrum within cloud. The latent heat released through condensation would appear to produce turbulent eddies within the cloud with sizes that fall preferentially in this wavelength range.

The data for cloud 10, collected on a directly into-wind pass (run 20-5), are presented as illustrations of the detailed measurements obtained for each run in Table 1. The rms gust velocities and average dissipation rate of 191 $cm^2 s^{-3}$ indicate that this cloud, which was not seeded and was not associated with any fire, was growing and very active. Time histories of the three gust components, event marker and dissipation rate are shown in Figure 4. The event marker shows that this cloud had two turrets with a 1.2 s (150 m) space between them. The time history of dissipation rate was computed using the method given above at 1 s intervals using a 2 s wide window of data. Peak dissipation rates greater than 2.5 times the in-cloud average are seen.

The gust velocity time histories show large excursions in all three components just within the downwind edge of the cloud. For the vertical trace, the large downdraft within the downwind (southern) edge of the cloud becomes a relatively smooth 3 m s^{-1} updraft in the center of the cloud. The shear in vertical gust velocity is about 12 m s^{-1} in 2 s of flight, or in about 250 m. Another interesting aspect of this particular gust is its horizontal extent. The entire downdraft occupies nearly 5 s of flight (~650 m) with approximately 70% of it outside the cloud.

The shape of the vertical gust trace resembles that of a giant vortex about a horizontal axis aligned perpendicular to the wind inside the cloud wall. The flow field can be more easily visualized with the aid of Figure 5, in which the side and plan views of the gust vectors have been plotted at 1/8 s (~15 m) intervals. Only data measured through the first cloud turret are shown, although the vertical velocity profile has a similar shape for the second turret. The flow field seen in side projection has the appearance of the abovementioned vortex about an axis centered below the flight level about 100 m within the cloud. The vertical projection, however, shows that the motion is not simply two-dimensional, but that the airflow is still vortex-like with the axis inclined at an angle to the horizontal.

4.0 CUMULUS CHARACTERISTICS

Contrary to what might be expected in cumulus cloud tops, the majority of peak vertical velocities measured were downgusts (Table 1). Most of these were sharp downdrafts encountered just within the edges of the clouds. Figure 6 shows time histories of the vertical gust velocity for 10 of the cloud top penetrations. The principal observation from these and other gust traces not shown, is that at these levels the cloud structure appears to be quite turbulent, and cannot be represented as a simple smooth updraft. Although there are notable updrafts to be seen in these clouds, they do not extend over the whole cloud width, but are instead relatively narrow in extent and usually separated by sharp downdrafts. The data have been studied to determine if the larger updrafts and downdrafts tend to occur in a consistent location in the cloud relative to wind direction, compass headings, etc. Although there is a slight trend toward downdrafts on the downwind edge of cloud tops, the data are too limited in number to form conclusions at this stage.

Figure 7 shows the rms velocity of turbulent fluctuations in the vertical (σ_w) plotted against the rms horizontal gusts (σ_h) in earth-fixed axes for both inside and outside the cloud for runs near cloud top. It is apparent that σ_w in-cloud is greater than σ_h in-cloud; the average ratio of σ_w/σ_h is 1.25. Immediately out-of-cloud, σ_w/σ_h has an average value of 1.05. The modal value of σ_w in-cloud is

approximately 1.7 m s^{-1}, while the modal value of σ_w immediately out-of-cloud is approximately 0.6 m s^{-1}. The high values of σ_w and σ_h in-cloud are comparable to updraft estimates used in cloud modeling. At present most cloud models, especially those with simple one-dimensional calculations, do not effectively simulate these high gust velocities.

Without exception, the dissipation rate in-cloud was greater than that out-of-cloud. For runs just within the bases of clouds 2 and 3, Table 1 shows that the turbulent energy dissipation rate was greater in-cloud than out-of-cloud but that the value was lower than that found near cloud top. Run 11-3 was made 150 m below the base of cloud 5 and the turbulent energy dissipation rate was only 18 cm^2 s^{-3}. Runs 18-5 and 21-5 were made in precipitation below clouds 8 and 11 and the turbulent energy dissipation rates were 50 and 41 cm^2 s^{-3}, respectively, or substantially lower than the dissipation rates measured near cloud top. The modal value for the in-cloud turbulent energy dissipation rate ϵ_u for the 26 runs near cloud top was 160 cm^2 s^{-3}.

Figure 8 shows ϵ_w in-cloud plotted against ϵ_u in-cloud with both energy dissipation rates being calculated in aircraft axes for runs near cloud top. For two penetrations, the value of ϵ_w was more than twice the value of ϵ_u. However, generally ϵ_w is only slightly greater than ϵ_u. This observation is important if an attempt is made to apply the formula

$$d^2 = \epsilon t^3, \tag{2}$$

which can describe the dissipation of a horizontal or vertical line source of particles as a function of time (t) and diameter (d) of plume (Kyle, 1974). Equation (2) is often used to describe the dispersion of AgI within a seeded cloud. In order to effectively apply this formula ϵ_u, ϵ_v and ϵ_w should be approximately equivalent. Figure 8 shows that this is a reasonable first approximation.

Equation (2) also demonstrates how the turbulent diffusion of particles within a cloud can mask any mean flow. For example, using a value of ϵ of 200 cm^2 s^{-3}, in 5(10) min, the diameter of a line source of particles would be 735(2078) m which corresponds to a mean flow velocity of 1.2(1.7) m s^{-1}. Figure 8 shows that ϵ is of often 200 cm^2 s^{-3} or greater.

5.0 AIRCRAFT LOADS

One reason for carefully studying the turbulence levels experienced in the cloud seeding experiment is the consideration of aircraft safety both for the current research aircraft and, if the technique proves effective, for future commercial seeding aircraft. Seeding cumulus clouds for forest fire suppression will be of little practical value if turbulence levels within the clouds to be seeded pose a threat to the seeding aircraft.

Of the 33 runs through the 17 clouds listed in Table 1, 26 were at the potential seeding level near the cloud top. The T-33 gust experience for these penetrations is presented in Figure 9 in terms of the peak vertical gust velocity and incremental g-load versus the rms values averaged over the cloud width. Positive and negative gust and acceleration peaks have been combined in this figure. The solid circles represent those runs through the tops of clouds located over forest fires. Although the sample size is small, it would appear that the clouds associated with forest fires are more turbulent than the average of all clouds penetrated in this study.

Run 7-6 accounted for the largest rms vertical gust velocity (4.0 m s^{-1}) and peak vertical gust (11.5 m s^{-1}) measured to date in this program. This peak gust produced a 1.1 g upward vertical acceleration increment on the T-33, still well below its design limit load increment of 6.3 g. The question is, however, for the levels of turbulence experienced by the T-33 in these cloud penetrations, what loads would result on other aircraft, particularly those likely to be involved in commercial cloud seeding.

A straightforward and reasonably accurate way to relate gust loads between aircraft is to use the derived-gust-velocity equation given by Pratt and Walker (1954):

$$\Delta a_z = \frac{m\rho_0 S V_e K}{2W} U_{de}, \tag{3}$$

where:

Δa_z	incremental aircraft vertical acceleration in g units
m	wing lift curve slope
ρ_0	air density at sea level
S	wing area
V_e	equivalent airspeed
W	aircraft weight
U_{de}	"effective" vertical gust velocity
K	gust alleviation factor [= $0.88\,\mu g/(5.3 + \mu g)$, where μg, the airplane mass ratio, is given by $2W/(m\rho cgS)$ and c is the aircraft wing chord, g the acceleration of gravity, and ρ the density at flight level].

Equation (3), embodying a number of simplifying assumptions, serves to relate the peak accelerations due to gusts to be expected on a given airplane to the peak accelerations measured on another aircraft for flight through the same rough air. The underlying concept is that a measured acceleration due to a gust may be used to derived an "effective" gust velocity, which in turn is used to calculate the acceleration on another aircraft by reversing the process. The gust velocity U_{de} need not be a direct physical quantity, but is rather a gust load transfer factor definable in terms of the formula. It is based on a gust shape represented by a (1 − cos) curve with the gust attaining its peak as the aircraft flies 12.5 chord lengths.

The analysis was conducted for the Twin Otter, a typical business jet (Lear 24), a light twin (Aztec), and for comparative purpose, a DC-8-50 to represent a large jet transport. Figure 10 presents the calculated peak vertical accelerations for these aircraft versus the peak accelerations measured by the T-33 during cloud top penetrations. The Aztec and Twin Otter had almost identical calculated responses, so only those for the Twin Otter are plotted. Note that for the aircraft studied, the calculated peak accelerations are lower than those experienced by the T-33. For the Twin Otter and Aztec, the much lower cruising speeds outweigh their reduced wing loading (W/S) to give a lower $\Delta a_z/U_{de}$ ratio than for the T-33. Accelerations for the DC-8-50 and other large transports are greatly reduced by their high wing loading. It must be remembered that the predicted smaller accelerations for the Twin Otter, for example, still represent a greater fraction of its design load than for the T-33 (2.4 incremental g-load for the Twin Otter as compared with 6.3 g for the T-33).

From ICAO recommendations (Dreyling, 1973), frequent gust-induced vertical acceleration increments of 0.5 to 1.0 g are considered as moderate turbulence, with accelerations greater than 1.0 g designating severe turbulence. Peak accelerations for the T-33 shown in Figures 9 and 10 indicate that the turbulence encountered on three of the cloud penetrations could be considered as severe. However, a person's judgment of the severity of turbulence is a function of not only the incremental acceleration level but also the duration of exposure to these accelerations. Figure 11 relates rms accelerations and exposure time to crew tolerance of turbulence (Sadoff et al., 1965). Root-mean-square accelerations from the 26 T-33 cloud penetrations have been plotted on this figure versus the time within cloud. Even the most turbulent case falls well within the tolerable range. This tends to confirm the impression of the flight crews that turbulence levels within the cumulus clouds studied to date have been light to moderate, with none that would be designated as severe.

6.0 CONCLUSIONS

MacCready (1964) suggested that moderate-heavy turbulence can be encountered when slow flying aircraft penetrate cumuli, and this report confirms that conclusion. However, from the above analysis and the T-33 turbulence data collected to date, penetrations of cumuli meeting the criteria outline in Section 3.0 should not pose a safety hazard for the types of aircraft studied (Fig. 10) and crew and passengers can easily tolerate the turbulence levels (Fig. 11). This conclusion is encouraging for the use of a cloud seeding technique which dispenses AgI from an aircraft flying through cumulus at the -5 to $-10°C$ level. This technique is presently being evaluated for use in a project designed to suppress forest fires by stimulating rain to fall from cumulus clouds passing over fires. It is interesting to note that pyrocumulus clouds clearly associated with forest fires may be more turbulent than naturally formed cumuli.

The characteristics of the 17 cumulus clouds studied indicate that the mean flow structure can be masked by turbulence. Few clouds exhibited the clearly defined updrafts and downdrafts as seen in Figures 4 and 5 for cloud 10. The large values of the rms gust velocities in-cloud on Figure 7 and the estimates of the turbulent diffusion rate of cloud particles suggest that turbulence is an important cloud physical process. A realistic cloud model should simulate this process so that the magnitude of effects of high turbulence levels on the dynamics and microphysical processes within clouds could then be assessed.

7.0 REFERENCES

1. Ackerman, B. — *The Nature of Meteorological Fluctuations in Clouds.* J. Appl. Meteor, 6, 1967, pp. 61-71.

2. *The Rate of Dissipation of Turbulent Energy in Cloudy Air.* Proc. Intern. Conf. Cloud Physics, Toronto, 1968, pp. 564-568.

3. Caiger, B.; Gould, D.G. — *An Analysis of Flight Measurements in the Wake of a Jet Transport Aircraft.* Proc. Aircraft Wake Turbulence Symp., Boeing Res. Labs., Seattle, 1970, pp. 125-136.

4. Cotton, W.R. — *On Parameterization of Turbulent Transport in Cumulus Clouds.* J. Atmos. Sci., 32, 1975, pp. 548-564.

5. Dreyling, H. — *An Airline's Experience on Turbulence.* Proc. AGARD Conf., No. 140, 1973, pp. 7.1-7.7.

6. Gould, D.G.; MacPherson, J.I. — *A Suggested Method for Estimating Patch Length from Turbulence Measurements Using Results from Low Altitude Flights by a T-33 Aircraft.* NRC, Aeronautical Report LR-562, National Research Council Canada, Ottawa, Ontario, 1972.

7. Gould, D.G.; MacPherson, J.I. — *Measurements of the Statistical Properties of Atmospheric Turbulence Below 1000 Feet.* NRC, Aeronautical Report LR-567, National Research Council Canada, Ottawa, Ontario, 1973.

8. Hacklinger, M. — *Design Problems of Military Aircraft as Affected by Turbulence.* Proc. AGARD Conf., No. 140, 1973, pp. 15-1—15-9.

9. Houbolt, J.C. — *On Turbulence Environment and Design Criteria.* Proc. AGARD Conf., No. 140, 1973, pp. 14.1-14.15.

10. Isaac, G.A.
MacPherson, J.I.
MacHattie, L.B.
Forest Fires and Cumulus Clouds.
NAE Misc. 51, National Research Council Canada, Ottawa, Ontario, 1975, 14 pp.

11. Kyle, T.G.
The Dispersal of Seeding Material in the Updrafts of Storms.
Preprints 4th Conf. Weather Modification, Ft. Lauderdale, Amer. Meteor. Soc., 1974, pp. 69-72.

12. MacCready, P.B., Jr
Standardization of Gustiness Values from Aircraft.
J. Appl. Meteor., 3, 1964, pp. 439-449.

13. MacPherson, J.I.
A Description of the NAE T-33 Turbulence Research Aircraft, Instrumentation and Data Analysis.
DME/NAE Quarterly Bulletin, 1972(4), National Research Council Canada, Ottawa, Ontario, 1973.

14. MacPherson, J.I.
Results of Intercomparison Flights Between the NAE T-33 and the NCAR Buffalo Atmospheric Research Aircraft.
NRC, Aeronautical Report LR-577, National Research Council Canada, Ottawa, Ontario, 1974.

15. Mather, G.K.
Some Measurements of Mountain Waves and Mountain Wave Turbulence Made Using the NAE T-33 Turbulence Research Aircraft.
DME/NAE Quarterly Bulletin, 1967(2), National Research Council Canada, Ottawa, Ontario, 1967.

16.
Measurements of Clear Air Turbulence Using an Instrumented T-33 Jet Aircraft.
Paper No. 68-36, Intern. Council Aeronaut. Sci., Munich, 1968.

17. Mather, G.K.
Treddenick, D.S.
Turbulence Measurements at Lower Levels Around a Squall Line.
NRC, Aeronautical Report LR-515, National Research Council Canada, Ottawa, Ontario, 1969.

18. McBean, G.A.
MacPherson, J.I.
Turbulence Above Lake Ontario: Velocity and Scalar Statistics.
Boundary-Layer Meteor. (in press), 1976.

19. Pratt, K.G.
Walker, W.G.
A Revised Gust Load Formula and a Reevaluation of V-G Data Taken on Civil Transport Airplanes from 1933 to 1950.
NACA Report 1206, 1954.

20. Sadoff, M.
Bray, R.S.
Andrews, W.H.
Summary of NASA Research on Jet Transport Control Problems in Severe Turbulence.
AIAA Paper No. 65-330, 1965.

21. Summers, P.W.
Mather, G.K.
Treddenick, D.S.
The Development and Testing of an Airborne Droppable Pyrotechnic Flare System for Seeding Alberta Hailstorms.
J. Appl. Meteor., 11, 1972, pp. 695-703.

22. Todd, C.J. *Ice Crystal Development in a Seeded Cumulus Cloud.* J. Atmos. Sci., 22, 1965, pp. 70-78.

23. Treddenick, D.S. *Turbulence Measurements In and Near Thunderstorms.* NRC, Aeronautical Report LR-534, National Research Council Canada, Ottawa, Ontario, 1970.

24. *A Comparison of Aircraft and Jimsphere Wind Measurements.* J. Appl. Meteor., 10, 1971, pp. 309-312.

TABLE 1

SUMMARY OF DATA FOR 33 RUNS THROUGH OR BENEATH 17 CLOUDS

Cloud No.	Flight-Run No.	Height Top m	Height Base m	Width m	Height Run m	No. Clds	Temp °C	Spec Hum. gm/kg	Wind Dir. °T	Wind Speed kts	Heading °T	Peak Gusts m/s	RMS In Cloud u m/s	v m/s	w m/s	RMS Out u m/s	v m/s	w m/s	ϵ_u In cm^2/s^3	Out cm^2/s^3	COMMENT
1	7-6	4860	2090	2120	4760	1	.4	2.4	-	-	157	11.5	2.0	3.3	4.0	.3	.2	.3	449	0.3	100m below top
1	7-7	4700	2090	4840	4600	5	-3.5	3.4	310	35	303	8.8	1.7	2.1	2.6	1.1	1.2	1.2	281	125	100m below top
2	8-4	2550	1990	2340	2450	3	12.3	3.3	326	25	290	4.1	1.4	1.1	1.4	.5	.4	.5	163	2.2	100m below top
2	8-3	2550	1990	4680	2090	6	13.0	6.4	294	24	129	5.0	1.0	1.3	1.6	.5	.5	.5	89	6.7	100m above base
3	10-4	3000	1180	1000	2840	1	-0.2	4.0	240	31	089	-6.5	1.4	.9	1.7	.2	.3	.3	82	1.6	160m below top
3	10-3	3000	1180	2190	1280	1	8.3	7.8	237	16	349	-2.9	.9	.6	.9	.6	.5	.6	24	8.5	100m above base
4	10-6	5170	1170	6720	3870	1	-7.9	3.3	253	24	219	-4.8	1.5	1.5	1.4	.5	.3	.4	102	1.2	1300m below top
5	11-1	3660	1400	3740	3510	2	0.7	3.8	247	21	296	8.7	2.0	1.3	2.2	.5	.6	.6	177	3.2	150m below top
5	11-3	3660	1400	9690	1250	-	14.0	11.0	235	14	277	-2.8	.7	.8	.8	.7	.8	.7	18	16	150m below base
6	16-1	7160	2740	11930	4940	1	-10.5	2.4	340	7	074	-3.4	.5	.7	.8	.2	.2	.2	6.7	0.5	near midpt of cld
6	16-2	7160	2740	8740	4910	1	-10.2	2.6	355	9	336	-4.1	.6	.7	.8	.6	.8	.6	8.7	7.6	near mid pt
7	18-1	4210	3230	810	3810	1	-8.4	2.7	296	31	019	3.1	.7	.4	.9	.2	.1	.2	9.7	0.3	400m below top
7	18-2	4210	3230	620	3780	1	-7.8	2.6	302	27	166	-2.6	1.0	.5	.7	.2	.1	.2	26	0.2	400m below top
8	18-3	3352	1520	1140	3170	1	-4.1	3.4	283	20	023	4.8	1.4	1.9	1.8	.2	.7	.2	387	0.2	180m below top
8	18-4	3352	1520	560	3050	1	-2.5	3.4	294	22	331	4.6	1.0	.8	1.4	.2	.2	.1	283	0.4	180m below top
8	18-5	3352	1520	-	1520	1	8.7	4.7	272	13	143	5.5	-	-	-	1.2	1.1	1.5	-	50	at base
9	20-1	3660	1220	1820	3350	2	-5.1	2.1	333	19	205	-6.6	1.3	1.3	1.9	.5	.4	.5	109	4.6	310m below top
9	20-2	3660	1220	3540	3350	1	-6.0	2.6	324	15	067	-4.9	1.4	1.5	1.5	.5	.9	.8	108	0.2	310m below top
9	20-3	3660	1220	3700	3350	1	-6.4	2.9	325	16	237	-5.0	1.1	1.6	1.4	.8	1.7	.8	92	2.0	310m below top
10	20-5	3720	1220	1060	3470	2	-6.8	2.2	348	16	332	-7.9	2.0	1.3	2.6	.4	.4	.7	191	4.5	250m below top
11	21-1	810	1680	2530	3350	2	-5.1	2.6	302	10	183	-7.8	1.5	1.5	2.1	.9	1.0	.7	219	26	460m below top
11	21-2	810	1680	840	3350	1	-4.9	1.9	332	6	080	-6.5	1.4	1.4	1.9	.5	.3	.6	248	4.5	460m below top
11	21-3	810	1680	-	1680		5.8	5.6	241	12	252	-2.9	-	-	-	.8	1.0	.9	-	29	at base
11	21-4	810	1680	-	1370		7.5	5.9	195	8	067	-3.6	-	-	-	1.0	1.0	1.1	-	36	310m below base
11	21-5	810	1680	-	1370		7.4	5.8	243	13	243	2.1	-	-	-	.8	.8	.6	-	41	310m below base
12	24-1	3660	1520	2830	3350	1	-5.3	3.4	280	29	189	-6.6	2.0	1.3	1.9	1.0	1.2	1.6	164	5.5	310m below top
12	24-2	3660	1520	2880	3350	1	-5.2	3.2	275	25	110	4.0	1.0	1.6	1.4	1.1	.8	.7	46	22	310m below top
13	25-1	5030		3340	4720	1	-3.1	5.1	234	25	226	-6.1	1.5	1.6	1.8	.7	.7	1.0	179	17	310m below top
13	25-2	5030		5590	4720	1	-3.0	4.5	248	50	180	-6.2	1.4	1.3	1.7	.7	.5	.6	103	11	310m below top
14	25-3	5030		2350	4630	2	-2.6	4.7	230	31	317	-5.3	1.8	1.6	2.1	1.1	.9	.5	212	46	400m below top
15	25-4	4730		1660	4420	1	-0.9	4.3	245	44	314	-4.5	1.1	1.5	1.6	.5	.4	.5	181	1.3	310m below top
16	25-5	5730		2460	5430	3	-7.1	3.1	242	35	242	-5.7	1.4	1.8	2.0	.8	1.0	.9	103	11	300m below top
17	25-6	5730		1250	5270	2	-6.2	3.1	243	48	125	5.4	2.4	1.9	2.1	.7	.9	.3	330	54	460m below top
													Earth-fixed Axes			Earth-fixed Axes			AC Axes		

The data shown are as follows: the cloud number, flight and run number; the height of the tops and bases of the cloud and its width along the track flown; altitude of the run, number of cloud elements penetrated; the average static temperature, specific humidity, wind direction and speed, and true heading of the track flown; peak vertical gust velocity (positive for an up-gust); the rms values of the three components of true gust velocity in earth-fixed axes for in-cloud and out; the average dissipation rate in and out of cloud computed from the longitudinal gust component in aircraft axes; and comments.

FIG. 1: NATIONAL AERONAUTICAL ESTABLISHMENT T-33 ATMOSPHERIC RESEARCH AIRCRAFT SHOWING NOSE-MOUNTED TURBULENCE BOOM, FUSELAGE POD HOUSING DOPPLER RADAR, AND AgI FLARE BURNING ON WING-MOUNTED POD

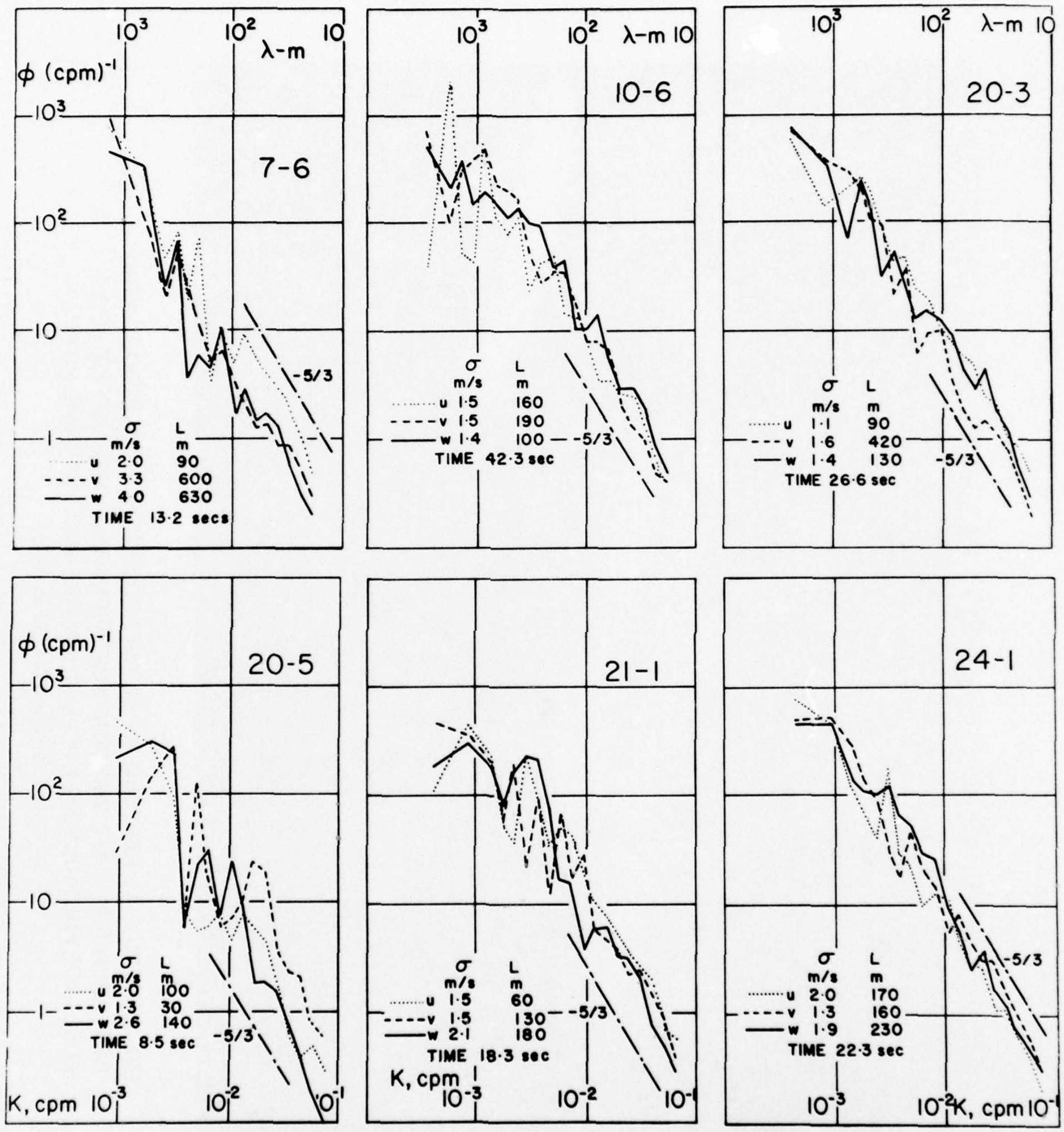

FIG. 2: NORMALIZED SPECTRA FOR THREE COMPONENTS OF TRUE GUST VELOCITY IN EARTH-FIXED AXES FOR SIX CLOUD PENETRATIONS

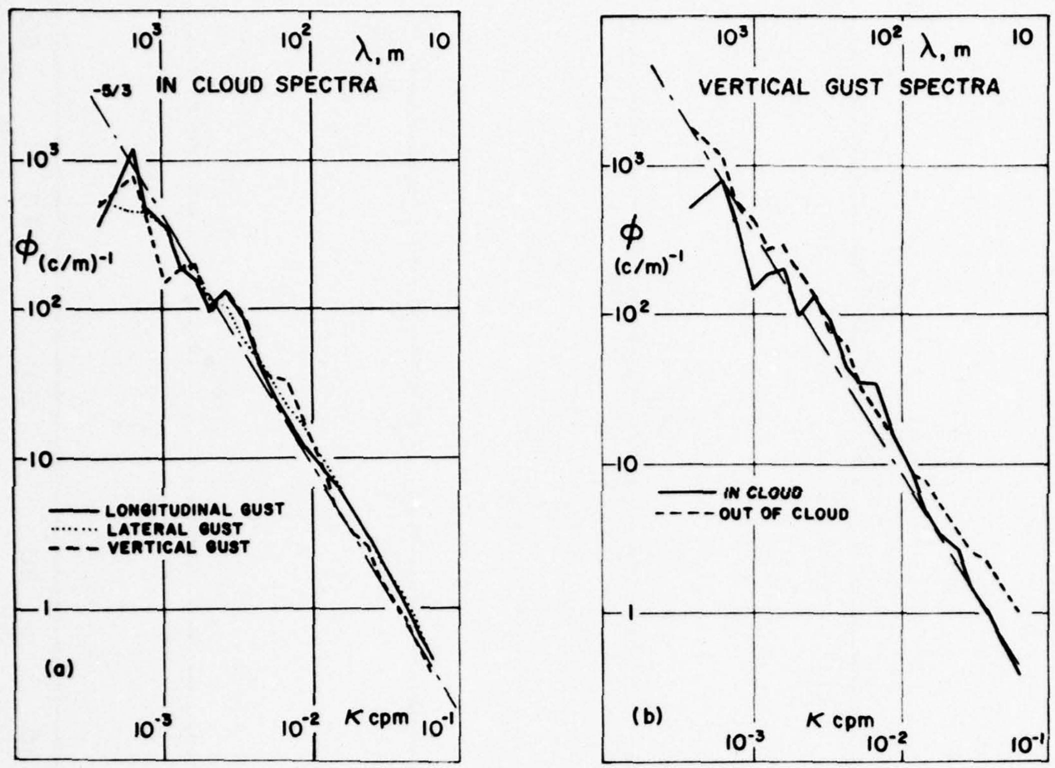

FIG. 3: AVERAGED NORMALIZED SPECTRA FOR 26 CLOUD-TOP PENETRATIONS FOR a) LONGITUDINAL, LATERAL AND VERTICAL COMPONENTS IN CLOUD; AND b) VERTICAL GUST COMPONENT IN-CLOUD AND OUT-OF-CLOUD

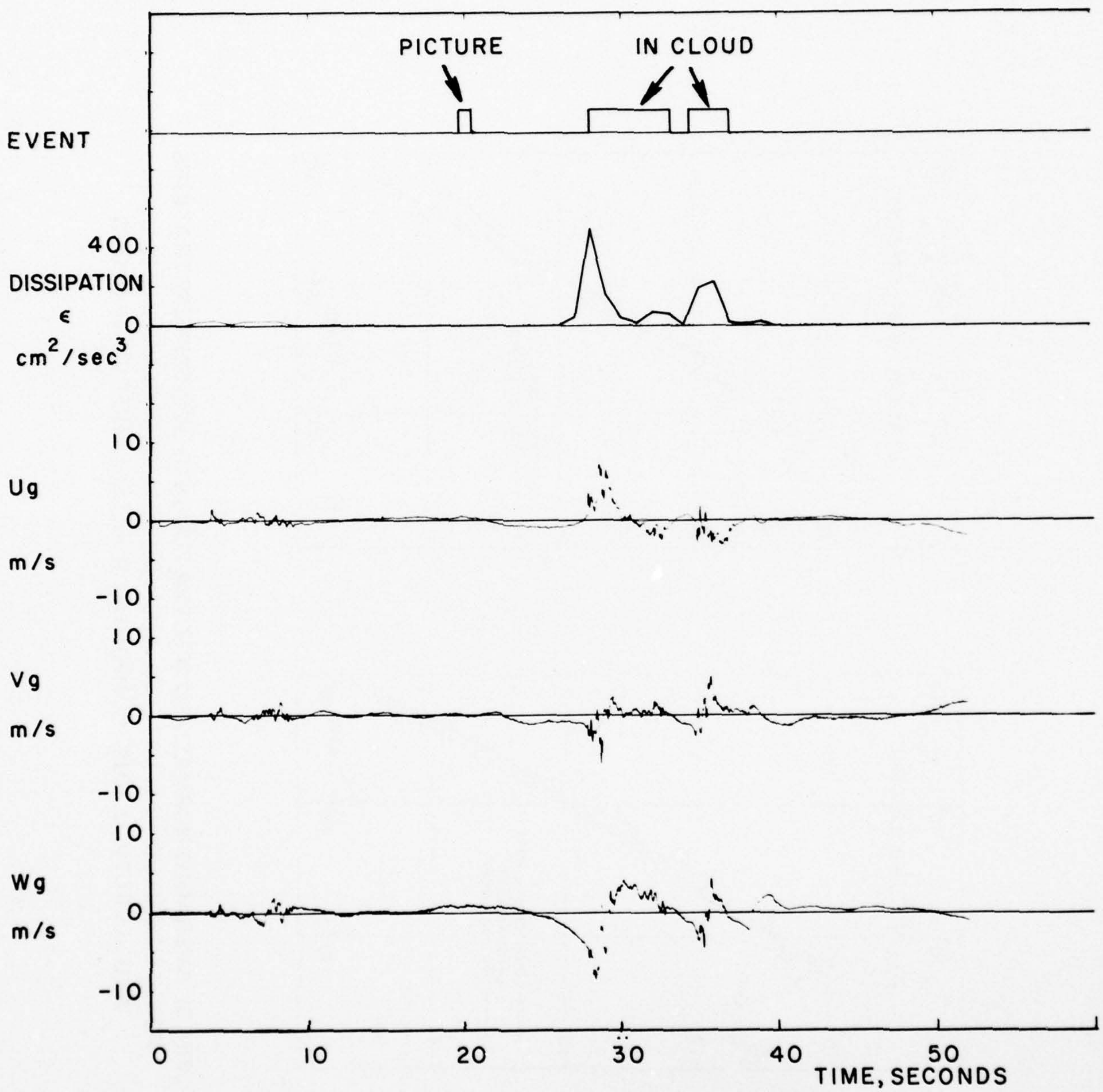

FIG. 4: TIME HISTORIES FOR EVENT MARKER, DISSIPATION RATE AND THREE COMPONENTS OF TRUE GUST VELOCITY FOR RUN 20-5

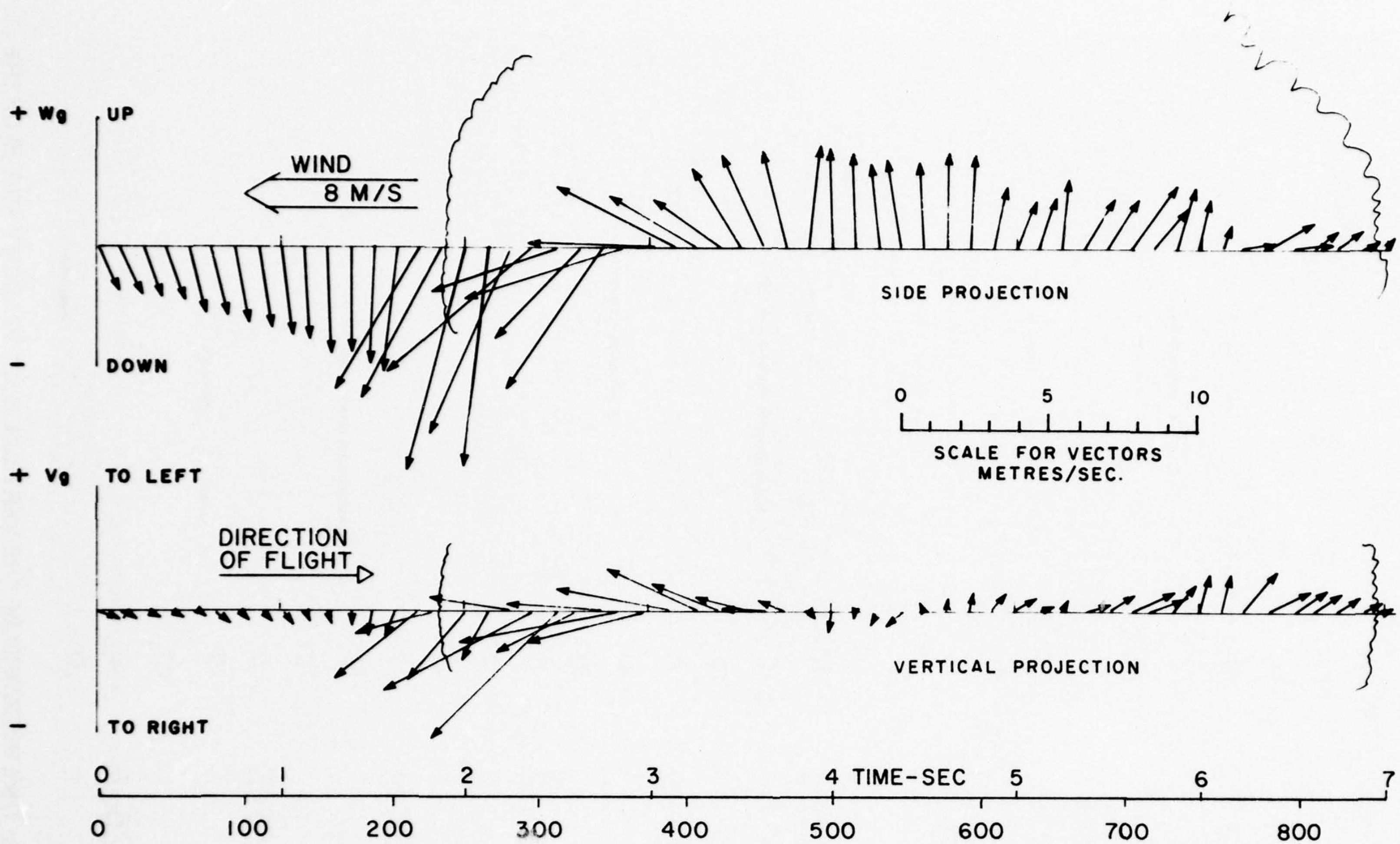

FIG. 5: SIDE AND VERTICAL PROJECTIONS OF GUST VECTORS FOR FIRST CLOUD ELEMENT PENETRATED IN RUN 20-5 (FIG. 4)

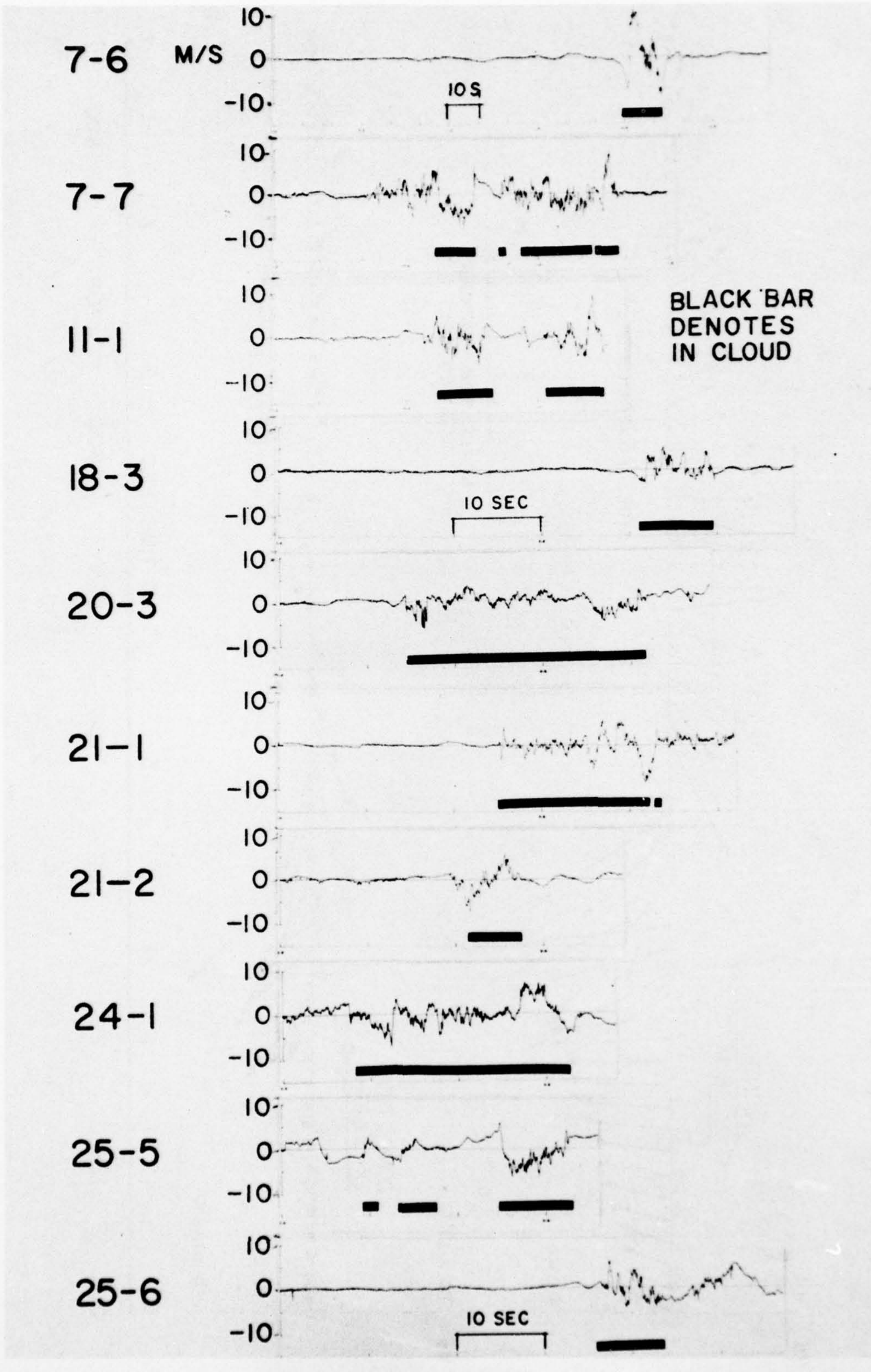

FIG. 6: TIME HISTORIES OF THE VERTICAL GUST VELOCITY FOR 10 OF THE CLOUD-TOP PENETRATIONS. TIME SCALES VARY AS SHOWN

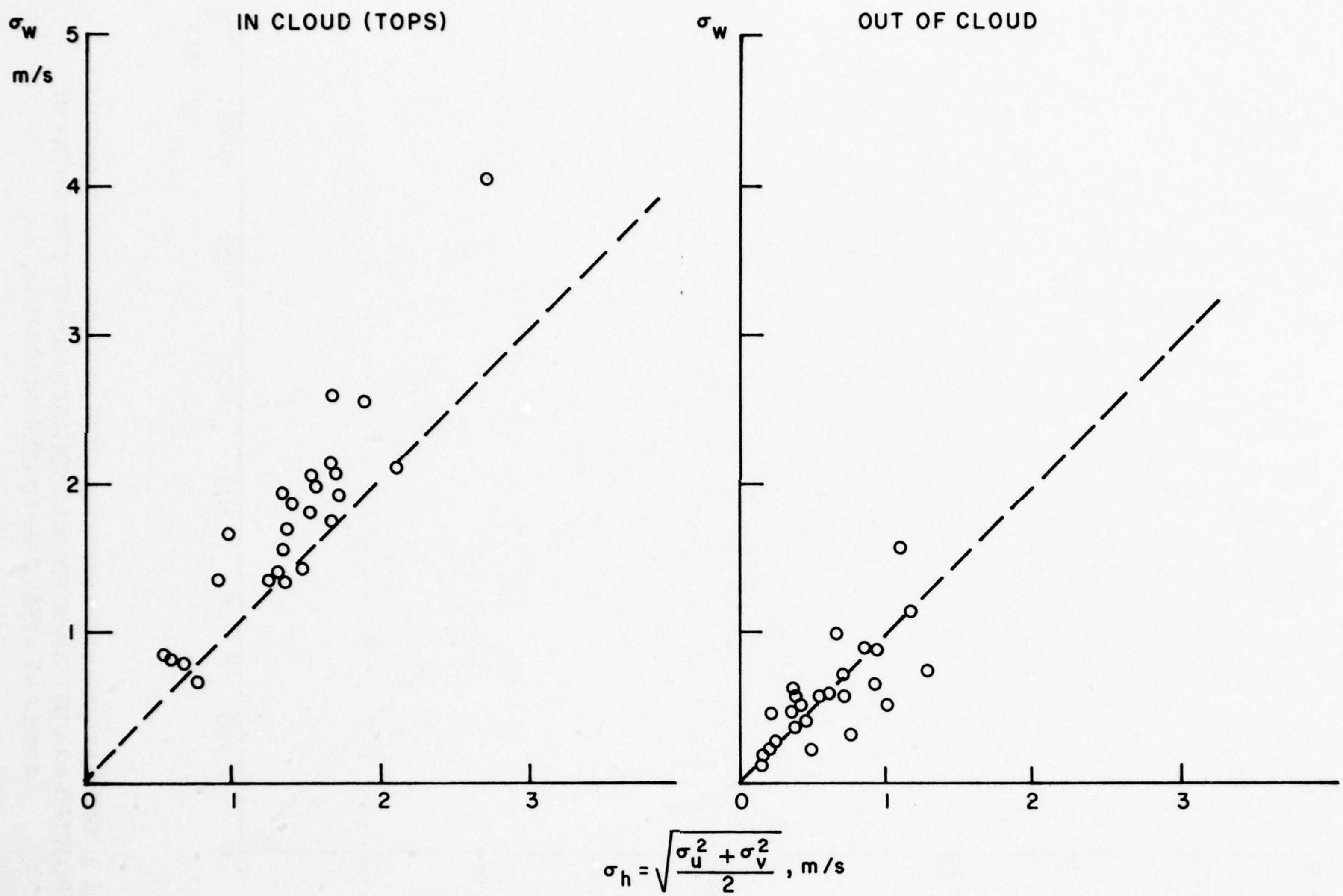

FIG. 7: VERTICAL VERSUS HORIZONTAL RMS GUST VELOCITIES FOR IN-CLOUD AND OUT-OF-CLOUD. DASHED LINE INDICATES $\sigma_w = \sigma_h$

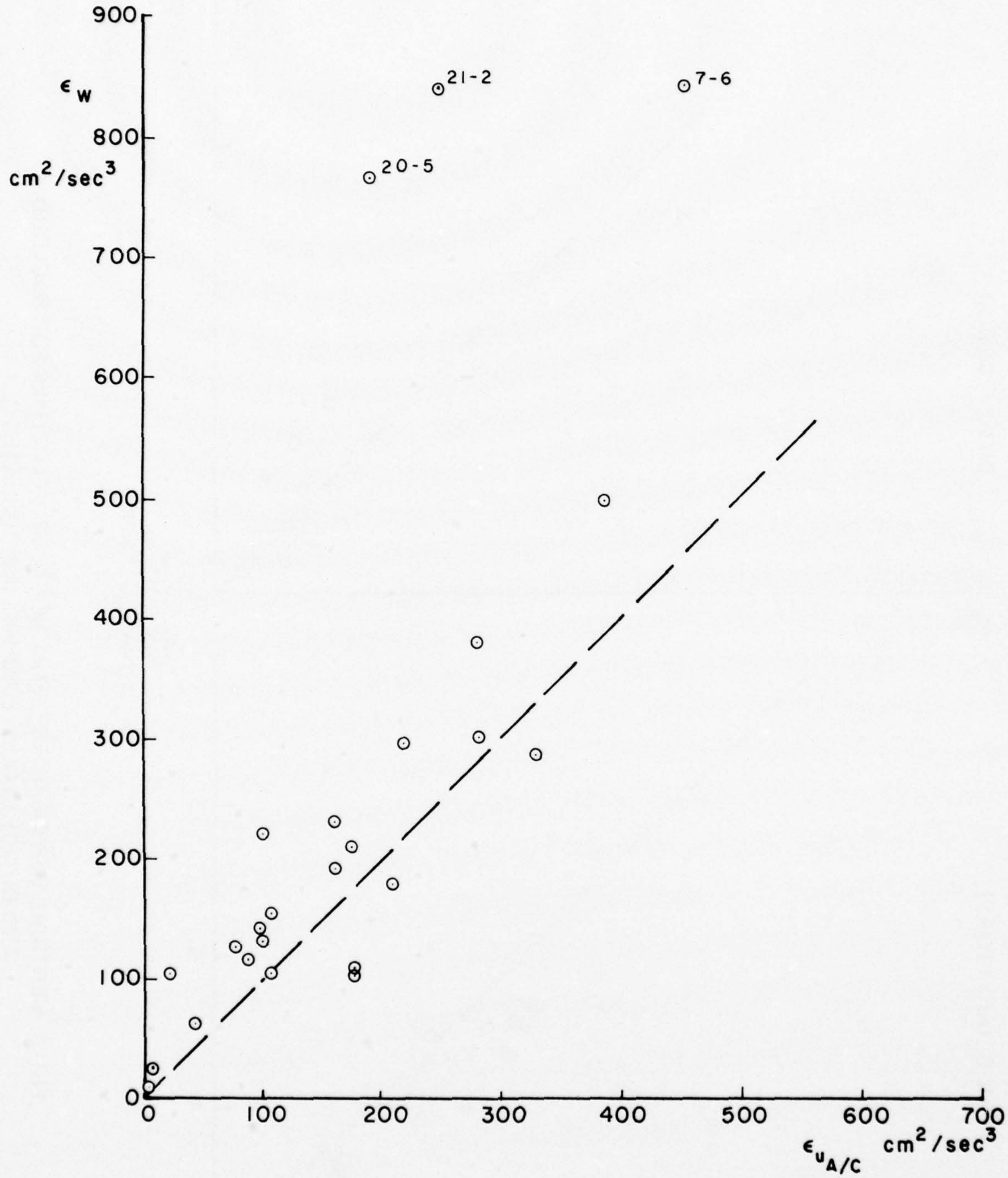

FIG. 8: DISSIPATION RATES COMPUTED FROM VERTICAL GUST COMPONENT PLOTTED AGAINST THOSE FROM LONGITUDINAL GUST COMPONENT IN AIRPLANE AXES. DASHED LINE INDICATES $\epsilon_w = \epsilon_u$

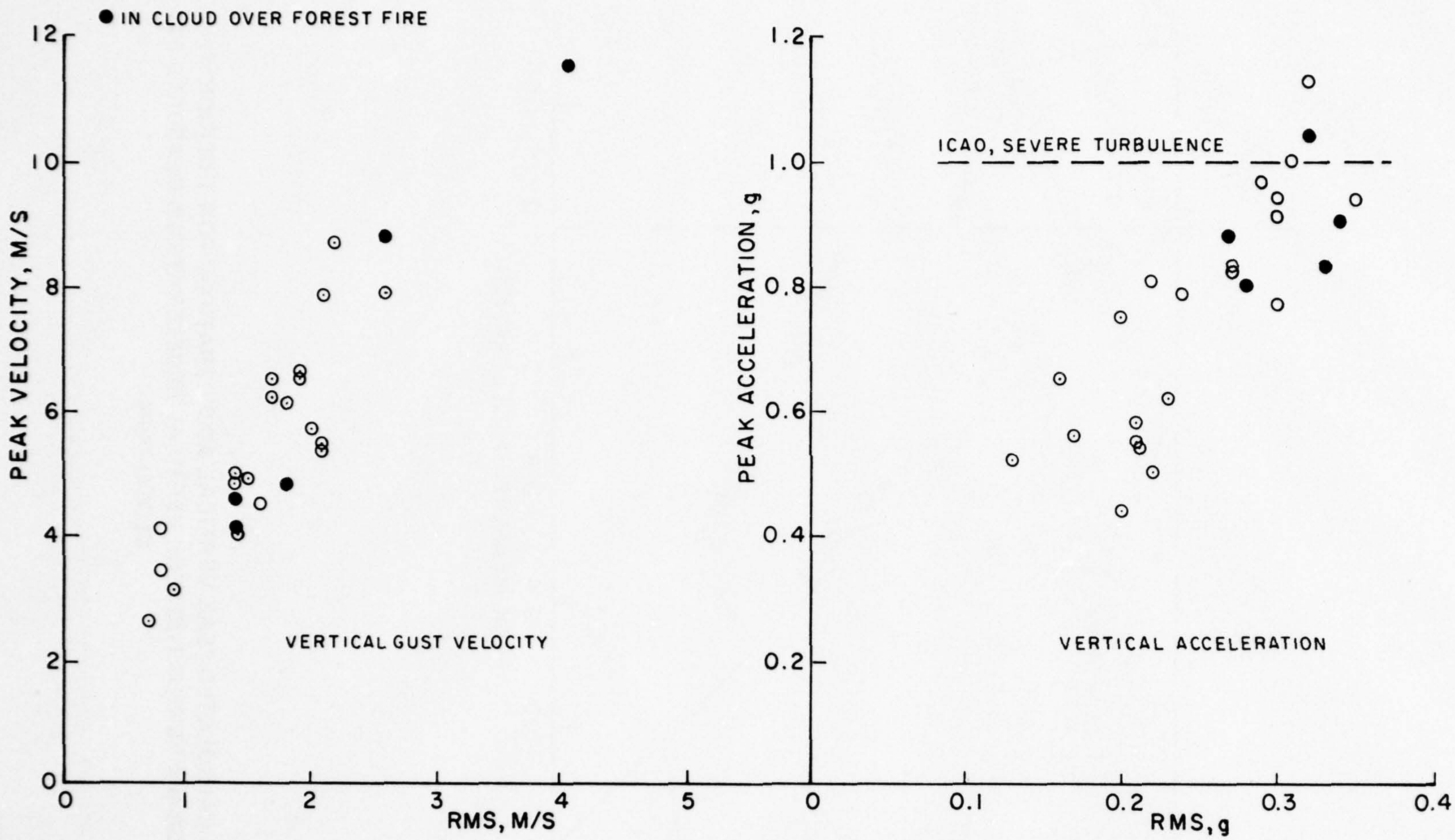

FIG. 9: T-33 VERTICAL GUSTS AND ACCELERATIONS EXPERIENCED DURING 26 CLOUD-TOP PENETRATIONS. ROOT-MEAN-SQUARE VALUES COMPUTED OVER THE CLOUD WIDTH ARE PLOTTED AGAINST THE ABSOLUTE VALUE OF PEAK EXCURSIONS

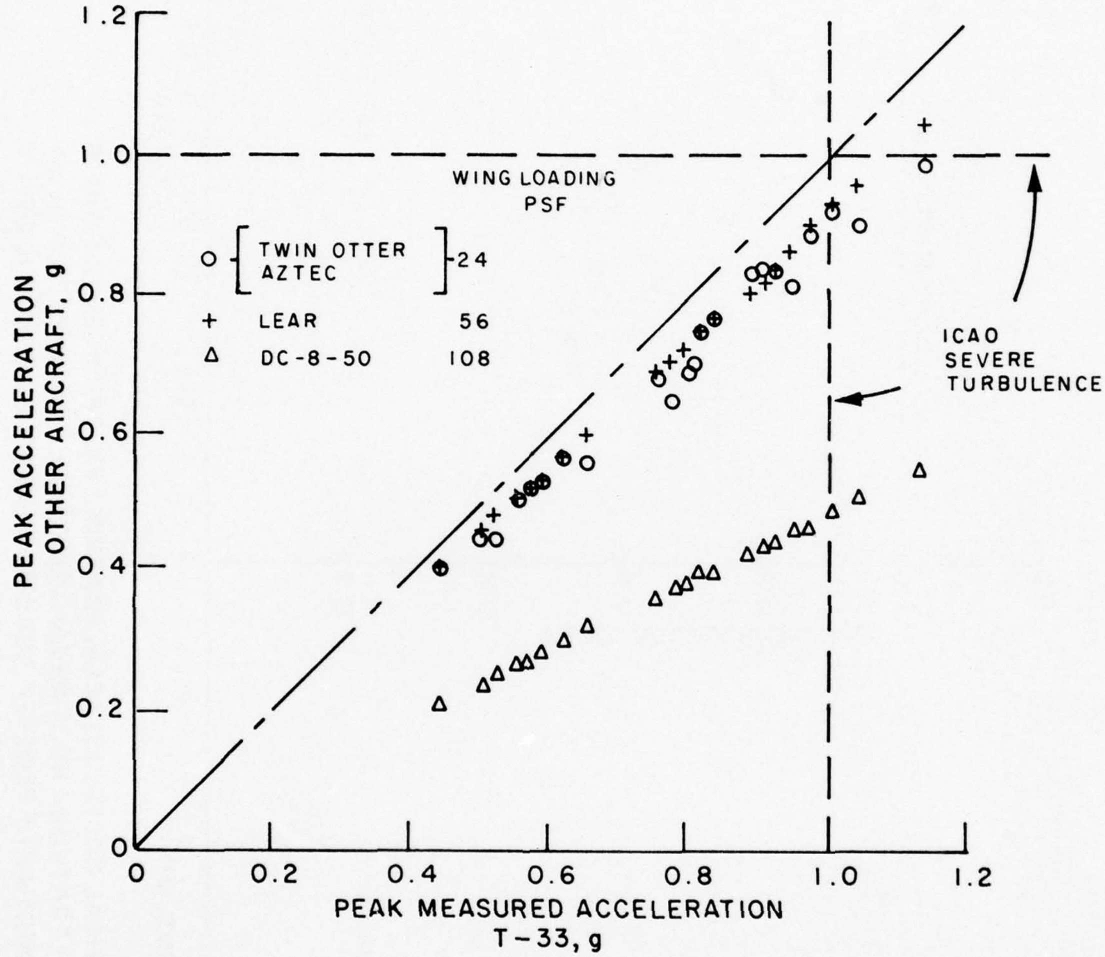

FIG. 10: CALCULATED PEAK VERTICAL ACCELERATIONS FOR THE INDICATED AIRCRAFT VERSUS T-33 PEAK VERTICAL ACCELERATIONS MEASURED IN CLOUD-TOPS

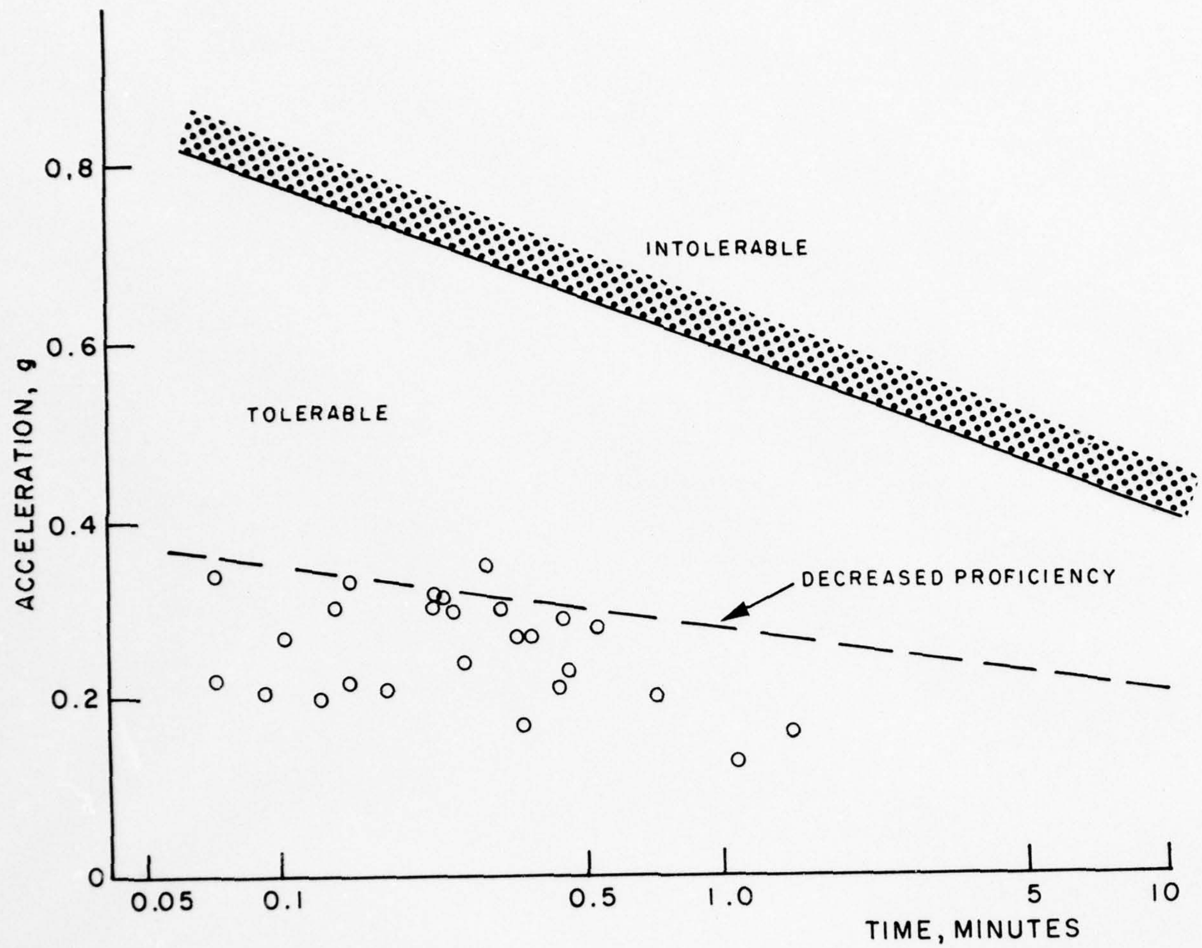

FIG. 11: ROOT-MEAN-SQUARE VERTICAL ACCELERATION MEASURED BY T-33 VERSUS TIME IN CLOUD COMPARED WITH THRESHOLDS OF CREW TOLERANCE TO TURBULENCE (FROM SADOFF et al., 1965)

MODE VERSUS AVERAGE IN CANADIAN CO-OPERATIVE FUELS AND LUBRICANTS EXCHANGES

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All petroleum products and lubricants possess certain properties that make them useful in particular applications. Gasoline is combustible, hence is useful as a fuel. It is also volatile, has good antiknock properties, (octane number), and is low in gum and sulphur compounds. It must have these and other properties to provide trouble-free, efficient engine operation. Lubricating oils obviously must have at least good lubricating characteristics, e.g., good antiwear properties, appropriate viscosity, non-corrosivity towards metals, freedom from contaminants.

Adjectives such as, "good", "low", "appropriate", etc., unfortunately are inadequate for defining properties. As far as possible numerical limits must be used. For winter-grade automotive gasoline, for example, the Reid vapour pressure (a measure of volatility by a standard test) is set at 9 to 14 psi, and total sulphur is set at 0.15% maximum. Virtually all lubricating oils must have a known viscosity measured at a standard temperature in a standard instrument under standard conditions, often expressed in centistokes units.

Specifications and classifications are available for these petroleum products and lubricants which show numerical limits for the various properties, and the standard tests by which they are measured. These are vital in trade between producers and consumers (or users). The Canadian Government Specifications Board (CGSB) and the Standards Council of Canada issue these at a national level. Many others also do exist, however, prepared by producers and consumers for their own use. Of course, the individual citizen does not have any, nor is he likely to understand them fully, and relies on the producer, competitive pressures and the distribution system including the service station or other outlet to give him "good" products. Reid vapour pressure and sulphur limits quoted earlier were taken from CGSB Specification 3-GP-1e for automotive gasoline.

Ordinarily, a property like Reid vapour pressure (RVP) of winter-grade gasoline is well within the 9 to 14 psi limiting range, and both producer and consumer laboratories will record a pass. (Incidentally, if the RVP of your winter gasoline is too low you are likely to experience difficulty in starting your automobile, if too high you could experience vapour lock leading to running or starting difficulties.) Because no two laboratories will get identical answers at all times reproducibility figures are assigned to each standard method. ASTM D323, the standard test for Reid vapour pressure, has a reproducibility of 0.3 psi, i.e., two laboratories are allowed to differ by this amount on the same sample of gasoline and are still considered to be in agreement with each other. Because of the broad RVP limiting range of 9 to 14 psi, disputes are not likely to arise even though the agreement is not as close as 0.3 psi. However, if the RVP of the sample is close to the 9 or 14 limit, a dispute may arise, especially if one or other of said laboratories inadvertently uses non-standard conditions and results differ by more than 0.3 psi.

Petroleum and lubricant testing laboratories recognize the limitations in the standard tests, and also appreciate the problems inherent in their own laboratories of keeping their equipment and testing techniques under standardized conditions at all times. One of the checks they employ is to participate in a co-operative program wherein they test sample portions of products periodically

distributed and compare their own results with those obtained by other laboratories and an exchange average. A valuable and generally successful program has been in operation under the auspices of CGSB for many years (Ref. 1). Indeed, the program comprises three exchanges:

1) a fuel exchange (monthly),

2) a lubricant exchange (monthly), and

3) a special products exchange (periodically).

The program has had one continuous deficiency, however. It has assumed that the average (mean) is at all times the true value of the property under measurement of the particular product sample under test. Statisticians say that the average serves this purpose only when the results received from co-operating laboratories are normally distributed, i.e., they follow a Gaussian or bell-shaped distribution curve (Fig. 1). The equation for the normal distribution curve is

$$y = (N/\sigma\sqrt{2\pi}) \exp(-x^2/2\sigma^2)$$

x deviation from mean value α

y (frequency) is number of results showing a deviation between $x - 1/2$ and $x + 1/2$ and σ is defined by the formula

$$\sigma^2 = [1/(N-1)] \sum_{i=1}^{N} y_i x_i^2$$

Mode (x) = α

API Gravity results on diesel fuels are, ordinarily, normally distributed as shown in this example (Fig. 2, Sample D-70). Note the even distribution of positive errors on the right and negative errors on the left, resembling the Gaussian curve (except for the absence of tails on the right and left in the histogram, a desirable feature).

In the histogram it is immediately apparent that 35.74, the average (or 35.75 rounded), is an excellent estimate of the true API Gravity of the sample as it coincides with the peak or mode favoured by the largest numbers of laboratories, i.e., eight laboratories at 35.7 and eight laboratories at 35.8. Laboratories can readily see their relative positions and calculate their departure or deviation from the true value as expressed by average or mode.

Many other properties, e.g., viscosity at 100°F and 210°F of lubricating oils, octane numbers of gasolines and zinc and calcium contents of lubricating oils when co-operatively tested usually give results that fall in a normal distribution.

However, some properties can be affected directionally either during handling, storage or testing leading to biases when reporting results. A set of results from co-operating laboratories in this instance will not show normal distribution, but skewing in the direction of the bias. The Reid vapour pressure test is sensitive to vapour losses which readily occur from handling, storage and testing. Excluding the customary random, unavoidable experimental errors that occur equally on the negative and positive side of the true Reid vapour pressure in a series of results submitted by co-operating laboratories, all of the laboratories will be faced with possible vapour losses. Those laboratories taking scrupulous care will be least affected; they will be affected only by random errors and will be in good company with each other generating closely agreeing results. Those laboratories taking less care will be

affected noticeably; their results will tend to be low and different as each will largely be affected differently by variable vapour losses depending on their handling of their sample portion. In fairness to the laboratories the finger of guilt can point to them in error if they happen to show a low bias. The sample distributor could have committed an error during sample portion preparation, or the container may have developed a leak in transit, both of which are out of reach of the testing laboratory yet the laboratory is tagged with the sin. Only if the laboratory shows a continuous bias on the samples received monthly can it be sure that the sin belongs to itself.

A histogram of RVP results from laboratories obtained on Sample M-411 shows clearly a skew to the left of the peak due, as noted earlier, to variable vapour losses leading to a variety of low results tending to disagree with one another (Fig. 3). Results under the peak and just to the right, and even just to the left which closely agree with one another, it must be assumed, were obtained carefully and in strict accordance with the procedure. They must carry much weight in determining true Reid vapour pressure. An estimate of the position of the peak, or mode, which is regarded as a good estimate of the true value of the property under measurement in a skewed distribution of results (and, in fact, normal or unskewed distributions as well where a mode and an average will coincide) is 13.8/13.9 psi for Sample M-411 vs the calculated average of 13.7 psi.

D. Muzyka (Ref. 2) selected an equation for estimating mode from average and other data provided in the CGSB exchange. From his equation an estimate of the mode for M-411 is 13.8 psi. As a rule of thumb following the examination of many samples tested for RVP he concluded that the mode of the RVP data for automotive gasolines would tend to be 0.2 psi higher than the average. On this basis the mode of M-411 would be 13.9 psi. Both values, upon examining the histogram, are in good company supported by seven laboratories (13.8 psi) and six laboratories (13.9 psi) in contrast to the average of 13.7 supported only by three laboratories and influenced by a host of different low values, some stretched to quite low levels.

Figure 3 and Table 1 show the theoretical frequency curve obtained by Muzyka's method superimposed on the histogram which is based on the actual measurements. The equation of the distribution curve is

$$y = [(0.4343 N/\sigma \sqrt{2\pi})/(2-z)] \exp\left\{-[\log(2-z) - \log\beta]^2/2\sigma^2\right\}$$

where $z = (10/13.7)\,x + 1$

and N is the total number of measurements, x is the deviation from the mean RVP (13.7 psi) and y (frequency) is the theoretical number of results showing a deviation between x - 0.05 and x + 0.05. The constants β and σ are obtained from the actual measurements by the formulae

$$\log\beta = (1/N) \sum_{i=1}^{N} y_i \log(2-z_i)$$

$$\sigma^2 = [1/(N-1)] \sum_{i=1}^{N} y_i[\log(2-z_i) - \log\beta]^2$$

The curve has a peak for

$$\text{Mode}\ (z) = 2 - \beta \times 10^{-\sigma^2/0.4343}$$

and therefore

$$\text{Mode}(x) = (13.7/10)\,[\text{Mode}(z) - 1]$$

One finds Mode (x) = 0.106. The peak of the curve (where y is plotted against x) is therefore at

$$13.7 + 0.106 \approx 13.8 \text{ psi}$$

The total number of measurements was 31 which statistically must be regarded as small. A greater number of measurements would, of course, give a histogram which would follow the theoretical curve much more closely.

TABLE 1

EVALUATION OF SAMPLE M-411

RVP Results Reported: 31

RVP Average: 13.7 psi

RVP (psi)	Deviation x	No. of Laboratories	Theoretical Frequency
12.6	-1.1	1	0.099
12.7	-1.0	0	0.155
12.8	-0.9	1	0.241
12.9	-0.8	0	0.368
13.0	-0.7	1	0.552
13.1	-0.6	1	0.812
13.2	-0.5	1	1.164
13.3	-0.4	0	1.617
13.4	-0.3	2	2.162
13.5	-0.2	0	2.762
13.6	-0.1	3	3.334
13.7	0.0	3	3.754
13.8	+0.1	7	3.875
13.9	+0.2	6	3.585
14.0	+0.3	4	2.885
14.1	+0.4	0	1.939
14.2	+0.5	1	1.027
14.3	+0.6	0	0.395
14.4	+0.7	0	0.097
14.5	+0.8	0	0.012

Drawing histograms to observe skewness appears advisable for all CGSB co-operative data (although admittedly it can be time consuming). A recent examination of the CGSB data has shown that skewness is more prevalent than at first thought. Some viscosity results at 210°F, some octane results, and Brookfield viscosity results at low temperatures were observed to be skewed. There is no

ready explanation for lubricating oil viscosity skewness; the test is usually subject only to random errors leading to a normal distribution of results. A skewness in the octane results can be attributed to vapour losses of light gasoline components. Apart from serving as a source of a mode, the histogram also clearly points out wild results.

Distributions of results can also show skewness to the right. This can occur in ash determinations when the ash content of a sample is very low or negligible Figure 4, Sample F-36. Traces of dust or dirt would tend to contribute to positive skewness (skewness to right) by giving erroneously a variety of high values to different sample portions tested by co-operating laboratories. Again it is not always apparent who is at fault: the testing laboratory or the distributing laboratory or a dirty container. However, the average of all results in a positively skewed distribution such as for the ash results shown is is obvously erroneous as the indicator of true ash value. It needs to be replaced by the mode, either estimated from the histogram or calculated from equations, such as the one suggested for RVP of gasoline. Wild results (0.008% and 0.010%) as shown in the histogram have exerted an undue influence on the average. They should have been rejected. Fortunately, when estimating the mode from the histogram, they are ignored.

An estimate of the mode of the ash content of F-36 from the histogram is clearly 0.0005%, and is a better estimate of true value than the average of 0.002% which, as already noted, is heavily influenced by the various high values. The two laboratories reporting 0.002% should not assume that they alone are correct; indeed the histogram indicates that their results are biased, albeit only slightly.

Many histograms, due to small numbers of results, are not shapely on first inspection. Skewness may not always be apparent. A closer grouping of the results usually brings out the shape clearly.

As shown, averages in skewed distributions of co-operative test results are not likely to give an accurate estimate of the true value of a property under measurement. Co-operating laboratories can be misled, then, in assessing their own performance, when comparing their result with an average (mean). The mode, or most popular value, either estimated from a histogram or calculated from a equation is considered to be a far better estimator of true value.

ACKNOWLEDGEMENT

The author wishes to thank Dr. R. Sandri for kindly determining the mode of the M-411 data and drawing the theoretical distribution curve based on Muzyka's formula.

REFERENCES

1. Operating Procedures and Monthly Exchange Results, CGSB Fuels and Lubricants Exchanges. Program Co-ordinator: Alberta Research Council, Gasoline and Oil Laboratory, Edmonton, Alberta, T6G 2C2

2. Muzyka, D. *Mode-Mean Differences in Skew Distributions of Co-Operative RVP Data.* NRC, DME, Laboratory Memorandum, F&L-37, April 25, 1977.

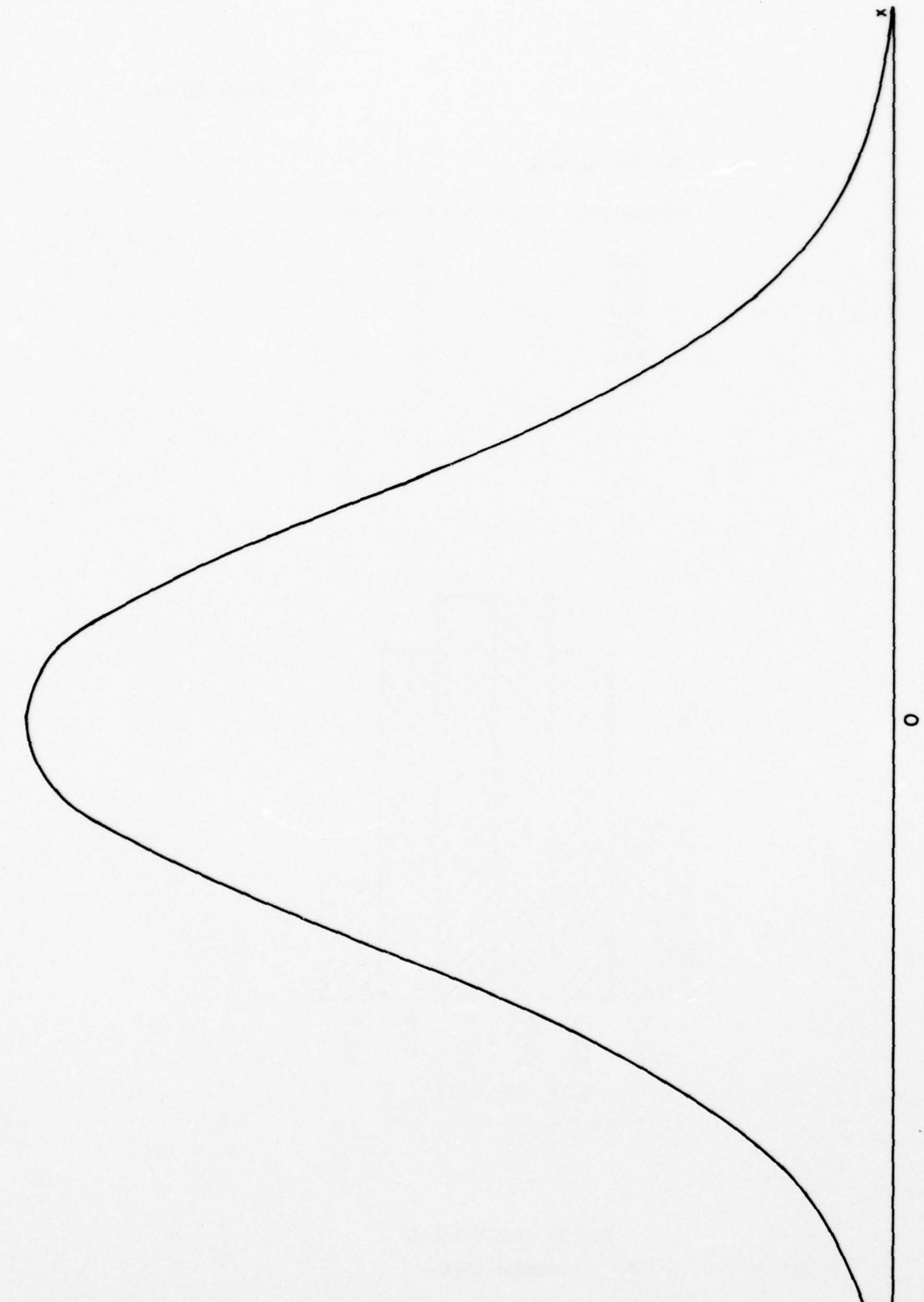


FIG. 1: THE NORMAL DISTRIBUTION

Average: 35.74

Results Reported:

API Gravity	No. of Laboratories
35.5	3
35.6	6
35.7	7
35.8	7
35.9	6
36.0	2

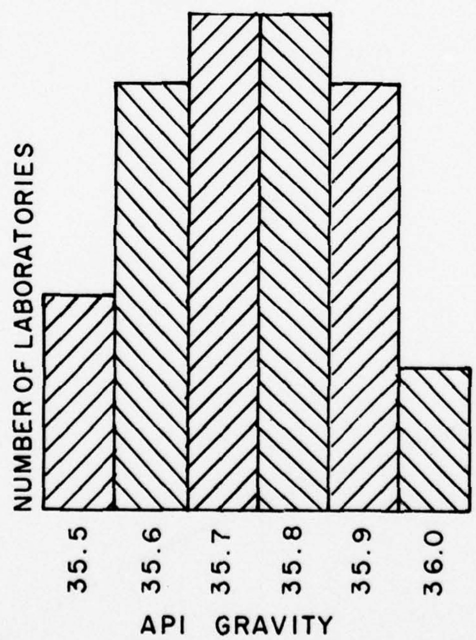


FIG. 2: HISTOGRAM
Sample: D-70

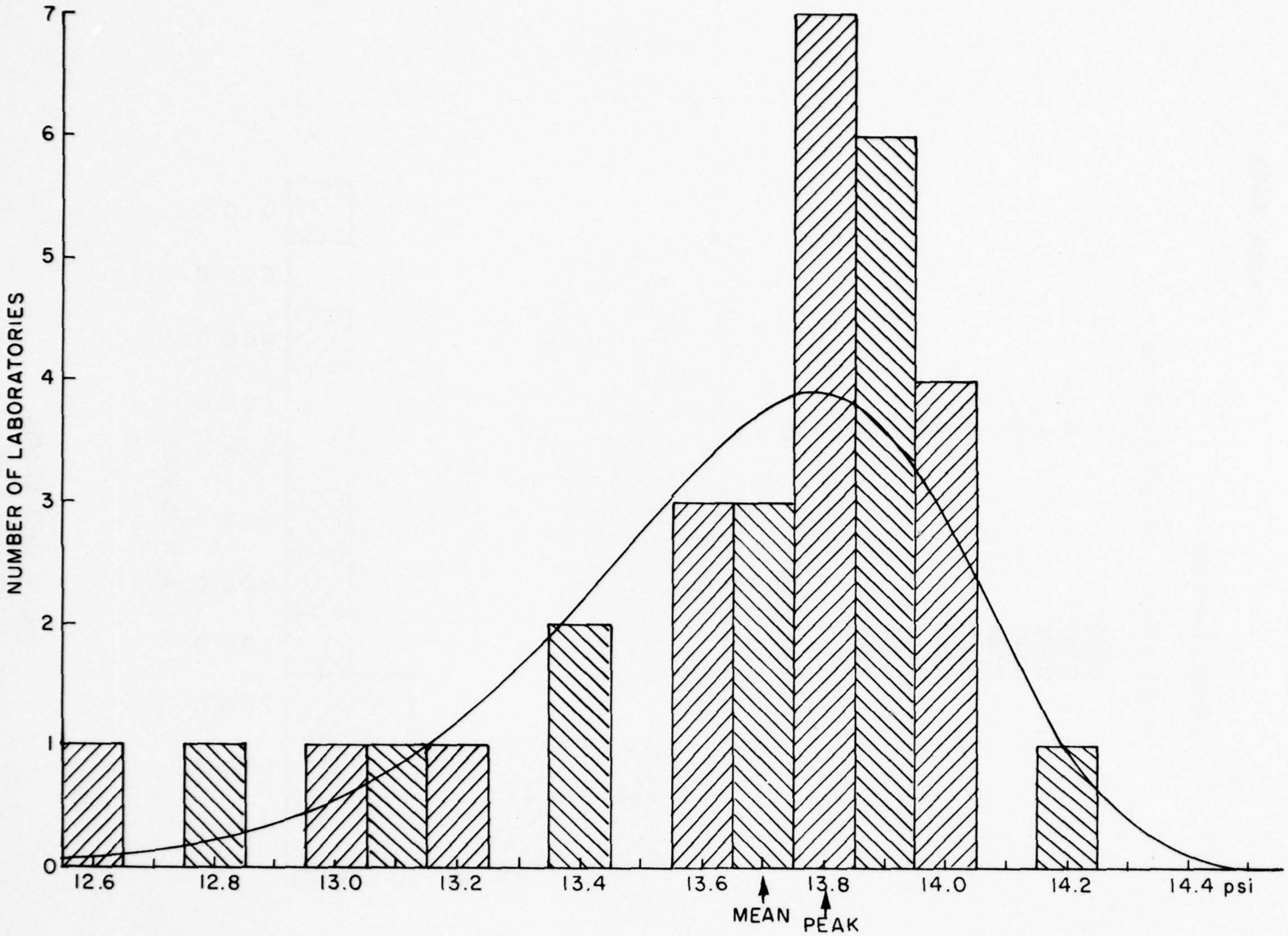


FIG. 3: THEORETICAL DISTRIBUTION CURVE SUPERIMPOSED ON HISTOGRAM
Sample: M-411

Average: 0.002

Results Reported:

ASH, % Mass	No. of Laboratories
0.000	6
0.001	6
0.002	2
0.003	1
0.004	1
0.005	1
0.006	0
0.007	0
0.008	1
0.009	0
0.010	1
Total Laboratories	19

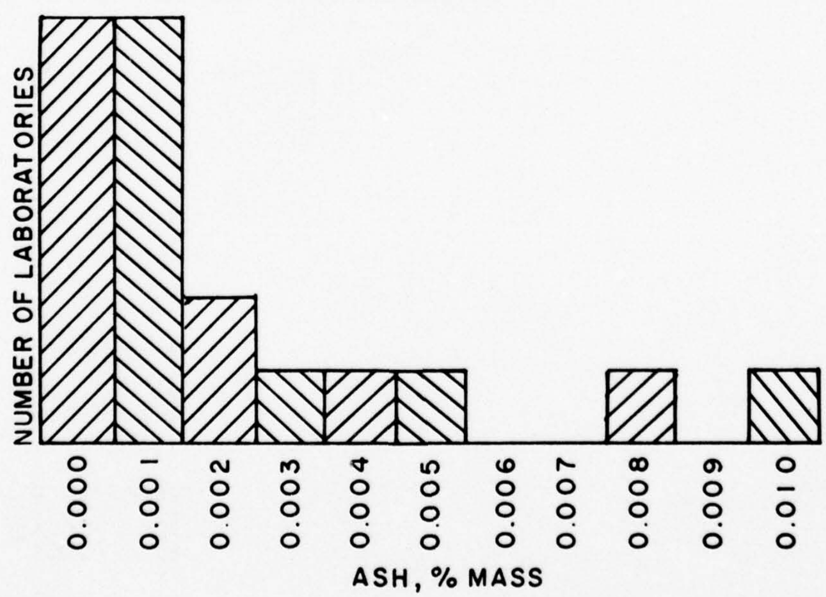


FIG. 4: HISTOGRAM

Sample: F-36

CURRENT PROJECTS

Much of the work in progress in the laboratories of the National Aeronautical Establishment and the Division of Mechanical Engineering includes calibrations, routine analyses and the testing of proprietary products; in addition, a substantial volume of the work is devoted to applied research or investigations carried out under contract and on behalf of private industrial companies.

None of this work is reported in the following pages.

ANALYSIS LABORATORY

AVAILABLE FACILITIES

This laboratory has analysis and simulation facilities available on an open-shop basis. Enquiries are especially encouraged for projects that may utilize the facilities in a noval and/or particularly effective manner. Such projects are given priority and are fully supported with assistance from laboratory personnel. The facilities are especially suited to system design studies and scientific data processing. Information is available upon request.

EQUIPMENT

1. An Electronic Associates 690 HYBRID COMPUTER consisting of the following:
   (a) PACER 100 digital computer
   - 32K memory
   - card reader
   - high speed printer
   - disc
   - digital plotter

   (b) Two EAI 680 analogue computer consoles
   - 200 amplifiers including 60 integrators
   - 100 digitally set attenuators
   - non-linear elements
   - x-y pen recorders
   - strip chart recorders
   - large screen oscilloscope

   (c) EAI 693 interface
   - 24 digital-to-analogue converters
   - 48 analogue-to-digital converters
   - interrupts, sense lines, control lines

2. Hewlett Packard Model 3960 FM instrumentation tape recorder. IRIG standard, 4-track, 1/4-inch tape. Speeds: 15/16, 3-3/4 and 15 inches per second.

GENERAL STUDIES

Study of methods for obtaining a mathematical model of a flexible articulated manipulator arm.

Curve fitting using cubic splines.

APPLICATION STUDIES

In collaboration with United Aircraft of Canada Ltd., a hybrid computer model of an advanced turbo-fan engine is being put together in order to investigate the expected performance of the engine and its control system.

In collaboration with the Railway Laboratory, a pilot hybrid computer model of the NRC roller rig for railway vehicle testing is being built as an aid in the design of the roller rig and its controls.

In collaboration with Aviation Electric Ltd., modeling work is underway in support of their advanced control concepts for both the small business jet engine and the helicopter engine. At present, a validation of a detailed model of a twin engine helicopter model is complete. Several detailed design studies have been completed and evaluation of one hardware configuration is underway.

In collaboration with the Control Systems and Human Engineering Laboratory and the International Nickel Co., Ontario Division, an interactive computer model of a copper-nickel smelter is being developed to study material handling and scheduling in the plant.

In collaboration with R.L. Crain Ltd., an interactive order streaming program for a print shop has been developed and is currently being evaluated by the press co-ordinators.

In collaboration with Canadian Westinghouse Ltd., a study is being made of the fuel controller requirements for a new family of industrial gas turbines. A hybrid computer model is being assembled to be used in the development.

In collaboration with Kendall Consultants Ltd., and SPAR Aerospace Products Ltd., a hybrid computer model of the remote manipulator arm being designed for the space shuttle is being assembled. The model is to include all allowable motions in three dimensions as well as arm flexibility effects.

In collaboration with the Urban Transit Development Corporation and G.F. Crate Ltd., a model of an Intermediate Capacity Transit System is being developed in order to study various system designs and resulting operational performance.

In collaboration with Northern Telecom Ltd., an interactive computer program is being developed to schedule cable orders on cable stranding machines.

In co-operation with Concordia University, a model of a heavy railroad freight vehicle is being assembled. Simulations of vehicle response to periodic and random excitations are to be conducted.

CONTROL SYSTEMS AND HUMAN ENGINEERING LABORATORY

INDUSTRIAL CONTROL PROBLEMS

Industrial systems and agricultural applications of fluidic circuits.

Fluid sensor and control component research and development.

Interactive computer modeling applied to operations scheduling of large scale industrial plants and processes.

Development of CAMAC instrumentation for industrial control applications.

Engineering support to specific firms for the implementation of schemes for control and mechanization.

HUMAN ENGINEERING – BEHAVIOURAL STUDIES

Investigation of the control characteristics of the human operator and the basic phenomena underlying tracking performance.

Investigation of the nature of sensory interaction in human perceptual-motor performance.

Investigation of the factors involved in the presentation and processing of information, particularly in relation to simulator design.

HUMAN ENGINEERING – MEDICAL AND SURGICAL

Investigation of the implementation of feedback control in living organisms with particular reference to the control of temperature and pressure in the spinal cord.

Development of heat exchangers for localized cooling of the spinal cord.

Measurement in-vivo of the mechanical impedance characteristics of skin and healed wounds.

Development of models of tissue sections, organs, and whole organisms.

Development of stereo-taxic and allied apparatus for neurosurgical procedures.

PATTERN RECOGNITION AND IMAGE PROCESSING

Investigation of the fundamentals of pattern recognition and their application to identification and classification problems with particular reference to image enhancement and computer analysis of human chromosome material from electron micrographs.

FULLY INSTRUMENTED VEHICLE UNDERGOING ROAD TESTS IN A STUDY OF THE RAM AIR EFFECTS ON THE PERFORMANCE OF THE COOLING SYSTEM OF A TYPICAL NORTH AMERICAN PASSENGER CAR. A CO-OPERATIVE RESEARCH PROGRAM BETWEEN THE ENGINE LABORATORY OF THE DIVISION OF MECHANICAL ENGINEERING AND CANADIAN INDUSTRY.

ENGINE LABORATORY

DIVISION OF MECHANICAL ENGINEERING

ENGINE LABORATORY

HOSPITAL AIR BED

A hospital air bed designed and built by NRC has been delivered to the Hotel Dieu Hospital in Kingston, Ontario for clinical evaluations of treatment of burn patients. The function and performance specifications of the bed were devised in collaboration with Canadian medical authorities to satisfy Canadian needs.

A second air bed was purchased in England by the Victoria Hospital in London, Ontario, and was adapted by NRC to meet Ontario Hydro requirements.

Several modifications were made to the NRC air bed as a result of the early testing experience. Both beds are being used very successfully for clinical evaluation. A study and an evaluation of the through flow characteristics of various support fabrics is underway.

GAS TURBINE OPERATIONS

An investigation of aircraft gas turbine engine operating characteristics is being conducted in conjunction with the Canadian Forces.

Assistance has been given to the Canadian Forces in the development of an inlet protective system for sea-borne gas turbines operating in icing environments.

DUCTED FAN AEROACOUSTICS

A 12-inch diameter ducted fan model has been tested aerodynamically for the purpose of making performance comparisons between a standard 19-bladed stator and a 19-bladed stator with stepped leading edges. Comparative noise studies of the same configurations in an acoustically treated test cell have recently also been completed.

These experiments are made by the Engine Laboratory in co-operation with the Division of Applied Physics with the intent of evaluating special noise reducing features in ducted fan design. Publication is in progress.

ENGINE COOLING SYSTEM PERFORMANCE

In collaboration with Canadian industry an experimental study is being made of automotive cooling fan performance with the fan in its actual engine bay environment and subject to normal ram air conditions. The study involves both road and wind tunnel tests at full scale under hot and cold radiator conditions. The test vehicle is typical of an intermediate size North American passenger car, and along with considerable in-vehicle instrumentation, is being provided by the industry for test purposes. Publication is in progress.

ROTOR DYNAMICS

An experimental rig has been constructed to investigate techniques for improved vibration signal diagnosis from rotating machinery under a variety of operating and support conditions. Test rotors are being designed.

The laboratory's torsional vibration calibrator is being modified to allow study of the effect of translational vibration on the performance of a belt-driven torsiograph.

AIR CUSHION VEHICLES

The first CASPAR program, on the Multicell skirt, has been completed. A report on this program has been issued, together with a supplementary report on the "hollow wall and pressurized cavity" development of this skirt system.

An analytical study of ACV drag overland is continuing. Advances in the theory have been formulated, and an experimental program is in progress, to explore the validity of these theories and provide numerical values for the coefficients proposed.

An associated study of skirt element structural stability and response to transient disturbances during forward motion is proceeding.

Research vehicle HEX-4 is being used for static stability tests, and drag measurement at various speeds and lift airflows. Special instrumentation for this work is incorporated in detachable pods on the vehicle.

HYDROSTATIC BEARINGS

The fabrication and testing of a hydrostatic bearing support system for the railroad roller test rig is in progress.

AEROACOUSTICS

A study of the noise characteristics of centrifugal blowers is in progress. An existing laboratory centrifugal fan has been tested to investigate the relation between flow characteristics and noise generation and to determine appropriate test procedures. The effects of certain changes in casing geometry on the noise generated by a commercial blower have been investigated.

AIR BEARINGS

Experimental and analytical work on air lubricated bearings and seals is continuing. Attention is being focused on aerostatic thrust bearings with one compliant surface.

HYBRID DRIVE VEHICLE SIMULATION

An all-digital computer simulation of hybrid drive vehicles is being developed. A model of the bladder accumulator system has been prepared and is being verified against an actual accumulator. Initially, a heat engine-hydraulic drive system will be modeled and verified against a prototype system installed in the Fuels and Lubricants Laboratory. At present, the model can handle a spark ignition engine coupled to an automatic transmission in an automobile.

NRC – PRATT & WHITNEY HIGHLY LOADED TURBINE

The test cell is in an advanced state of preparation and installation of test fixtures is underway. A data acquisition and reduction system has been delivered and will be used on this experiment.

FLIGHT RESEARCH LABORATORY

AIRBORNE MAGNETICS PROGRAM

Experimental and theoretical studies relating to the further development of airborne magnetometer equipment and its application to submarine detection and geological survey, are currently in progress. The North Star flying laboratory has now been retired but analysis of magnetic data taken over east, west and Arctic coasts of Canada will continue for some time to come. Studies are continuing in very low frequency (VLF) and other navigation methods to support long range geophysical surveys. A Convair 580 aircraft to replace the North Star is currently being equipped with new magnetometer and computing systems.

INVESTIGATION OF PROBLEMS ASSOCIATED WITH V/STOL AIRCRAFT OPERATIONS

The Laboratory's Bell 205A1 variable stability helicopter is being employed in programs to investigate terminal area operational problems which are most severe for or peculiar to aircraft capable of low approach speeds. The 205, which is capable of measuring and recording the magnitude of the three components of motion of the atmosphere through which it flies, is employing this capability in a program of terminal area wind and turbulence documentation at the Rockcliffe STOLport. In a related program the 205 is being configured to simulate the flight characteristics and handling qualities of a powered-lift STOL transport aircraft. The effects of severe turbulence and strong wind shears on the approach handling qualities and operational envelope of such an aircraft are being evaluated by flying the simulated vehicle through naturally occurring atmospheric disturbances.

INVESTIGATION OF ATMOSPHERIC TURBULENCE

A T-33 aircraft, equipped to measure wind gust velocities, air temperature, wind speed, and other parameters of interest in turbulence research, is used for measurements at very low altitude, in clear air above the tropopause, in the neighbourhood of mountain wave activity, and near storms. Records are obtained on magnetic tape to facilitate data analysis. The aircraft also participates in co-operative experiments with other research agencies, in particular, the Summer Cumulus Investigation (see below). A second T-33 aircraft is used in a supporting role for these and other projects.

AIRCRAFT OPERATIONS

The Flight Recorder Playback Centre is engaged in the recovery and analysis of information from the various flight data recorders and cockpit voice recorders used on Canadian military and civil transport aircraft. The military systems are being monitored on a routine basis. Civil aircraft recorders are being replayed to investigate incidents or accidents at the request of the Ministry of Transport. Technical assistance is being provided during incident and accident investigations and relevant aircraft operational problems studied.

INDUSTRIAL ASSISTANCE

Assistance is given to aircraft manufacturers and other companies requiring the use of specialized flight test equipment or techniques.

INVESTIGATION OF SPRAY DROPLET RELEASE FROM AIRCRAFT

Theoretical and experimental studies of spray droplet formation from a high speed rotating disc have been conducted. Flight experiments utilize a Harvard aircraft modified to carry external spray tanks. Automatic flying spot droplet and particle analysis equipment is in operation for processing samples obtained in the laboratory and in the field by various agencies. The equipment has potentialities for the analysis of many unusual configurations provided that these may be photographed with sufficient contrast.

AUTOMOBILE CRASH DETECTOR

There is a need for a sensing device to activate automobile passenger restraint systems in incipient crash situations. Investigations are in progress to determine the applicability of C.P.I. technology to this problem.

SUMMER CUMULUS INVESTIGATION

At the request of the Department of the Environment flight studies of Cumulus cloud formations over Quebec and Ontario were instituted during the Summer of 1974. Instrumented T-33 and Twin Otter aircraft with a Beech 18 are being used to determine the properties of Cumulus clouds which extend appreciably above the freezing level. The measurements are being made to assess the feasibility of inducing precipitation over forest fire areas by seeding large cumulus formations. During 1975 a variety of cloud physics instruments were added to the Twin Otter, and special pods for burning silver iodide flares were attached beneath the wing of the T-33 turbulence research aircraft. The effects of seeding on the microstructure of individual cumulus clouds were studied in the Yellowknife area during the summers of 1975 and 1976. This project is planned to continue for several years.

FUELS AND LUBRICANTS LABORATORY

COMBUSTION RESEARCH

Experiments on fuel spray evaporation.

Investigation of handling and combustion problems involved in using hydrogen as a fuel for mobile prime movers.

Study of possible methods for destruction of oxides of nitrogen in engine exhaust gas.

Evaluation of the use of mixtures of methane and carbon dioxide as automobile fuels.

Co-operative studies with Advisory Group for Aerospace Research and Development (AGARD) Working Group 11 to produce a report on aircraft fire safety.

EXTENSION AND DEVELOPMENT OF LABORATORY EVALUATION

Development of new laboratory procedures for the determination of the load carrying capacity of hypoid gear oils under high speed conditions and under low speed high torque conditions.

Evaluation of filter/coalescer elements for aviation turbine fuels.

Evaluation of longlife filter/coalescer elements from aviation turbine fuel service.

PERFORMANCE ASPECTS OF FUELS, OILS, GREASES, AND BRAKE FLUID

Investigation of laboratory methods for predicting flow properties of engine and gear oils under low temperature operating conditions.

Co-operative investigation covering test procedure for the evaluation of thermal oxidation stability of hypoid gear lubricants.

Development of a laboratory method for the evaluation of oil performance in air-cooled two-stroke engines.

Investigation of the electrostatic charging tendency of distillate fuels.

Evaluation of static dissipator additives for distillate fuels.

Evaluation of properties of re-refined oils and by-product sludges.

Investigation of the use of anti-icing additive in aviation gasoline.

MISCELLANEOUS STUDIES

The preparation and cataloguing of infra-red spectra of compounds related to fuels, lubricants, and associated products.

The application of Atomic Absorption spectroscopy to the determination of metals in petroleum products.

Investigation of the stability of highly compressed fuel gases.

Analytical techniques for analysis of engine exhaust emissions.

Participation in the Canadian (CGSB), American (ASTM) and International (ISO) bodies to develop standards for petroleum products and lubricants.

The design and development of an internal combustion engine/hydraulic transmission hybrid power plant for the energy conserving car.

Further developments of specialized pressure transducers for engine health diagnosis and the development of diagnostic techniques and consultation with licencee in developing production methods for patented transducers.

Evaluation of various products, fuels, lubricants and hardware in respect of their effects upon overall vehicle fuel economy and energy conservation properties.

GAS DYNAMICS LABORATORY

V/STOL PROPULSION SYSTEMS

A general study of V/STOL propulsion system methods with particular reference to requirements of economy and safety.

INTERNAL AERODYNAMICS OF DUCTS, DIFFUSERS AND NOZZLES

An experimental study of the internal aerodynamics of ducts, bends, diffusers and nozzles with particular reference to the effect of entry flow distortion in geometries involving changes of cross-sectional area, shape, and axial direction.

SHOCK PRODUCED PLASMA STUDIES

A general theoretical and experimental investigation of the production of high temperature plasma by means of shock waves generated by electromagnetic and gasdynamic means, and the development of diagnostic techniques suitable for a variety of shock geometries and the study of physical properties of such plasmas.

NON-DESTRUCTIVE SURFACE FLAW DETECTION IN HOT STEEL BILLETS

An eddy-current surface flaw detector is being developed, using a special coil system by which a three-phase modulated R.F. signal is being electrically rotated round the billet at a rate given by the modulation frequency. The system displays the angular position of the flaw on a polar oscilloscope sweep or numerically, while the signal amplitude represents the depth of the flaw.

HIGH PRESSURE LIQUID JETS

High speed water jets generated by pressures in the range of 1000 to 60,000 psi can be used for cutting a wide variety of materials, e.g. paper, lumber, plastics, meat, leather, etc., and for cleaning surfaces such as masonry, rocks, tubular heat exchangers, etc. Nozzle sizes, depending on the application, are in the range from 0.002 to 0.15 in. diameter. A technique for manufacturing small nozzles in the range 0.002 to 0.015 has been developed using standard sapphire jewels available from industry. Larger orifices are manufactured and polished using standard shop procedures.

At present, the following investigations are active in the laboratory:

1. Intensive development of a rotating seal designed and developed in the laboratory. It appears to have great potential, especially for industrial cleaning, quarying and possibly for drilling operations.
2. Experiments on the fracturing of rocks using continuous and cavitating jets.
3. Experiments for clearing ice off runways and for cutting through thick ice ridges.
4. Experiments on the production of intermittent jets with high stagnation pressures.

Emphasis is now being placed on the study of effects produced by cavitating jets, how best to produce them and where they may be usefully applied.

HEAT TRANSFER STUDIES

Initial development of a temperature control thermosiphon for an electronic package has been successfully concluded. Life testing of this device has commenced.

An investigation of methods of increasing boiling and condensing heat transfer coefficients by treatment of the heat transfer surface has begun.

A co-operative project with the Division of Building Research will determine the usefulness of the thermosiphon as a ground heat source for a heat pump.

Work has started on extending the range of design information for use in air-to-air heat recovery units.

Current co-operative projects with manufacturers and users include:

(a) Combustion studies for industrial gas turbine applications (Westinghouse and Rolls-Royce).

(b) Application of thermosiphon as an energy conserving device in industrial applications (Dept. of Agriculture, Ministry of Transport, Farinon Electric, Chromalox Canada Ltd.
(c) Power turbine nozzle vane studies (Westinghouse).
(d) Scaled model studies to establish the performance of complex industrial flue systems with a view to establishing specific design and performance criteria (Noranda and Inco Canada Ltd.).

COMPUTATIONAL FLUID DYNAMICS

To support the experimental work, numerical simulations are being developed in three areas.

Single-pulse jets from vertically-accelerated liquid-filled rotating cones. This is a two-dimensional, axisymmetric, unsteady, incompressible flow problem with a free surface, where the liquid is subjected to large body accelerations.

Fluid dynamics of laser-produced plasmas. The phenomena are considered as two-dimensional, axisymmetric, unsteady, compressible flow problems in which real gas behaviour is considered. The approach, which uses Lagrangian formulation, has been used to calculate two cases:

(a) The fluid dynamics of a laser breakdown plasma, with the objective of explaining the mechanism of beam re-entry into the plasma when beam intensity is reduced.

(b) The interaction of a CO_2 laser beam with magnetically confined plasmas. This major problem is currently being studied numerically as part of a co-operative effort with the Aerospace Research Laboratory of the University of Washington.

Shock dynamics and fluid dynamics resulting from synchronized spark discharges on the axis and discharges on the perimeter of a cylindrical vessel containing hydrogen, to achieve high gas temperatures on the axis of the vessel.

GAS TURBINE BLADING STUDIES

A program on the theoretical and experimental study of the performance of highly loaded gas turbine blading has been undertaken as a collaborative program with industry and universities.

INDUSTRIAL PROCESS, APPARATUS, AND INSTRUMENTATION

There is an appreciable effort, on a continuing basis, directed towards industrial assistance. This work is of an extremely varied nature and, in general, requires the special facilities and capabilities available in the laboratory.

Current co-operative projects with manufacturers and users include:

(a) Flow problems associated with industrial gas turbine exhaust systems (Foster Wheeler).
(b) Combustion studies for industrial gas turbine applications (Westinghouse and Rolls-Royce).
(c) Application of thermosiphon as an energy conserving device in industrial applications (Dept. of Agriculture, Ministry of Transport and Farinon Electric).
(d) Scaled model studies on steel and copper converters to establish relative performance and ceramic liner deterioration rates (Canadian Liquid Air and Noranda).
(e) High pressure water jet applications in industry (High Pressure Systems Ltd.).
(f) Power turbine nozzle vane studies (Westinghouse).
(g) Scaled model studies to establish the performance of complex industrial flue systems with a view to establishing specific design and performance criteria.

HIGH SPEED AERODYNAMICS LABORATORY

RENEWAL OF THE TURBULENCE DAMPING SCREENS IN THE 5-FT. × 5-FT. WIND TUNNEL

In more than 14 years of use, during which it has been operated more than 19000 times, the 5-ft. × 5-ft. blowdown wind tunnel has incurred failures in various components, notably the turbulence screens.

Owing to the impossibility of replacement without major dismantling of primary structure, successive removals of ruptured turbulence damping screens have culminated in a situation where the working section flow quality is only marginally acceptable. Four of the original seven screens have been removed.

The full complement of screens will be restored in a rebuild of the settling chamber later this year. In addition the substitution of a more flow restrictive second baffle in the wide angle diffuser, for the existing one, will be made. This will result in a reduction of the destructive turbulence in the flow entering the settling chamber, which, with an improved means of suspending the turbulence damping screens, should give an increase in the working life for the replacement screens. Significant improvement in test section flow quality is also expected.

To establish a firm schedule for the strip and rebuild has been extremely difficult due to the many elements involved and postponement of this operation has been a regular occurrence. However, as of the beginning of July, the wind tunnel is effectively shut down and preparatory work for dismantling commencing. It is hoped to have the complete refurbishing operation completed by the end of October, 1977.

CALIBRATION OF THE 5-FT. × 5-FT. WIND TUNNEL'S TRANSONIC TEST SECTION

Measurements of flow angle and stagnation pressure distribution across the width of the test section at mid height are currently being made prior to the imminent strip and rebuild. Nine four-hole, conical-head yawmeters with closely coupled pressure transducers are mounted on a support wing. These should furnish steady-state and r.m.s. values of the flow angles.

The angularity measurements will be followed by stagnation pressure measurements in which the profile of pressure unsteadiness are sought. Nine pitot tubes with closely coupled pressure transducers are available.

Following the replacement of the full number of turbulence reducing screens these measurements will be repeated at a later date. It is hoped that some valuable data affecting blowdown wind tunnel design will be generated.

SETTLING CHAMBER STUDY IN 5-IN. × 5-IN. WIND TUNNEL

Revisions to the settling chamber of the 5-ft. × 5-ft. wind tunnel are under consideration to improve the flow distribution and to decrease the level of pressure fluctuation at the entry to the stilling section. Model tests are being conducted in the NAE pilot faci facility, to determine the effect of increasing the resistivity of the second porous (dished) baffle in the wide angle diffuser ahead of the stilling section, and the installation of a "trimming" screen at the exit of the acoustic baffle geometry. Furthermore, studies of the effect of modifications to the cruciform-cone structure at the entrance of the wide angle diffuser on the settling chamber flow are also being conducted.

TWO-DIMENSIONAL TRANSONIC FLOW STUDIES

Efficient computer programs based on finite difference procedures are available for the design of supercritical airfoils and for the analysis of supercritical flow. A small disturbance transonic program is being developed and will include wind tunnel wall effects.

HIGH REYNOLDS NUMBER PIPE FLOW

This investigation is carried out at the request of and in co-operation with Laval University, Quebec.

The object is to obtain turbulent skin friction data at very high Reynolds number (Re_d up to 20×10^6) in an 8-in. pipe. The investigations to date include calibration of a range of Preston and razor blade surface pitot tubes and mean velocity traverses. Turbulence and noise measurements are also being considered. Analysis of the Preston tube calibration data has been carried out and the results agree well with semi-empirical theory based on the logarithmic wall law.

A floating element skin friction balance has recently been supplied by Laval University and initial tests have been carried out.

THEORETICAL AND EXPERIMENTAL STUDY OF JET NOISE

Further investigations of internal noise in a low speed jet are in progress. More detailed studies of the interaction of the transmitted sound with the jet flow and some statistical investigation of the multiple wave scattering by the turbulent eddies will be carried out. Some experiments on co-axial jets have been performed and measurements of pressure fluctuations in the turbulent shear layer has been undertaken. Turbulence measurements will be carried out by laser Doppler velocimeter.

Wave-like large scale eddies have been shown to be the basic characteristic of free turbulent shear flows. For circular jets, measurements of the wave development have been made for the axisymmetric mode of propagation. Recent experiments show that the

jet can also support wave propagation in helical modes. Some detail measurements have been performed. A paper on the helical mode study will be published in the AIAA Journal.

HIGH REYNOLDS NUMBER SUBSONIC FLOW SEPARATION

Preliminary tests in the 5-ft. × 5-ft. tunnel were carried out during April and again in May. Flat plate boundary layer data were obtained at M = .3 over a Re_x range of 3×10^6 to 1.5×10^8, using instrumentation described in the previous issue of Q.B. Also, similar data was obtained at $Re_x = 1.1 \times 10^8$ over a M range of .3 to .9. Step-induced separate flows were studied over the same conditions referred to above. The step height to boundary layer thickness was varied between .2 to 2.5 at selected conditions. Further tests are planned following renewal of the turbulence damping screens, after which it should be possible to determine the influence of free-stream turbulence.

REYNOLDS NUMBER EFFECTS ON TWO-DIMENSIONAL AEROFOILS WITH MECHANICAL HIGH LIFT DEVICES

A multi-component airfoil model, based on a supercritical airfoil, has been designed and manufacturing is in progress. The model will be equipped for pressure measurements on all components and provision is also made for boundary layer – wake surveys in the vicinity of the airfoil surface. The model is part of a program aimed at a detailed analysis of 2-D high lift flow and the effect of Reynolds number on the optimum flap settings.

Work on an iterative solution of the compressible boundary layer flows about multi-element airfoil is continuing at the University of Manitoba.

TESTS IN THE 5-FT. × 5-FT. BLOWDOWN TUNNEL FOR OUTSIDE ORGANIZATIONS

SAAB-Scania, Sweden

Reynolds number effects on the lift, drag and static stability characteristics of various swept-wing-body configurations were investigated in the Mach number range $0.5 < M < 0.985$, using a half-model arrangement.

HYDRAULICS LABORATORY

ST. LAWRENCE SHIP CHANNEL

Under the sponsorship of the Ministry of Transport, a study to improve navigation along the St. Lawrence River, using hydraulic and numerical modeling techniques.

NUMERICAL SIMULATION OF RIVER AND ESTUARY SYSTEMS

Mathematical models have been developed to simulate tidal propagation in estuaries, wave refraction in shallow water and littoral drift processes.

DEVELOPMENT OF SPECTRAL ANALYSIS PROGRAMS

For use in the analysis of wave records and on-line analysis of turbulent diffusion data produced in the laboratory.

WAVE FORCES ON OFF-SHORE STRUCTURES

Wave flume study to determine design criteria for off-shore mooring structures.

RANDOM WAVE GENERATION

A study of random waves generated in a laboratory water wave flume by signals from a computer.

MIRAMICHI CHANNEL STUDY

The hydraulic and numerical model studies of the effect on deepening the navigation channel in the Miramichi Estuary have been completed. A report has been issued to the Steering Committee for this Study.

LOCK MODEL STUDY ON VESSEL SIZE

In co-operation with the Marine Dynamics and Ship Laboratory a model study has been undertaken to determine the effect of vessel and lock dimensions on the entrance and exit speeds of ships in locks of the St. Lawrence Seaway.

STABILITY OF RUBBLE MOUND BREAKWATERS

A flume study for the Department of Public Works to determine stability coefficients of armour units and the effect of a number of wave parameters on the stability of rubble mound breakwaters.

WAVE LOADS ON CAISSON TYPE BREAKWATERS

A flume study for the Department of Public Works to determine the overall loading, as well as the pressure distribution on various Caisson-type breakwaters.

WAVE POWER AS AN ENERGY SOURCE

A general study to assess the wave power available around Canada's coast and to evaluate various proposed schemes to extract this energy. International co-operation is taking place through the International Energy Agency of OECD.

MOTIONS OF LARGE FLOATING STRUCTURES, MOORED IN SHALLOW WATER

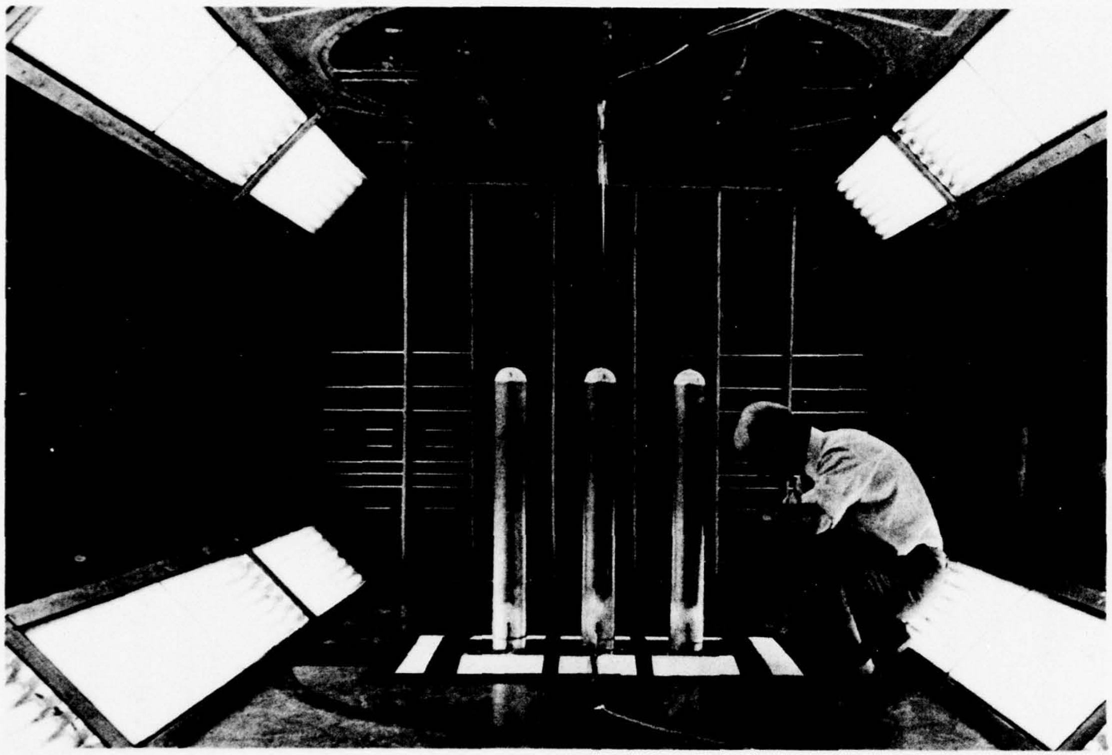
A mathematical and hydraulic modeling program will be carried out to develop techniques and methods to forecast motions of, and mooring forces on large structures moored in shallow water.

PORT ELGIN HARBOUR MODEL STUDY

A hydraulic model study to investigate wave agitation in the harbour basin at Port Elgin, Lake Huron for Public Works, Canada.

SAULNIERVILLE HARBOUR MODEL STUDY

A hydraulic model study and wave flume study to relocate a breakwater at Saulnierville, N.S. to give better protection.



1:39 SCALE AEROELASTIC MODEL OF PROPOSED ALCAN BAUXITE DIGESTER TOWERS FOR SAN CIPRIAN, SPAIN AND SHANNON, IRELAND IN 6-FT. X 9-FT. WIND TUNNEL

LOW SPEED AERODYNAMICS LABORATORY
NATIONAL AERONAUTICAL ESTABLISHMENT

LOW SPEED AERODYNAMICS LABORATORY

WIND TUNNEL OPERATIONS

The three major wind tunnels of the Laboratory are: the 15-ft. diameter, open jet, vertical tunnel; the 6-ft. X 9-ft. closed jet, horizontal tunnel; and the 30-ft. V/STOL tunnel. During the quarter, 13 programs were undertaken which included work for Canadair Ltd., DeHavilland Aircraft of Canada Ltd. and the Wind Engineering Group of the Laboratory.

WIND ENGINEERING

The construction of a 1:100 scale model of the Olympic Stadium is well advanced. Wind tunnel investigations of the proposed removable portion of the stadium roof will begin in the next quarter. The work is being done for the Olympic Installation Board.

Measurements of wind properties are being made on the Lions' Gate Bridge, Vancouver as part of a aerodynamic investigation of the bridge. There are four anemometers distributed along the span and two accelerometers to measure bridge motion. A fully automated recording system has been installed. Site assistance is being provided by Buckland and Taylor Ltd., Vancouver.

In collaboration with the Ontario Ministry of Transportation and Communication and the Canada Safety Council, field observations have been made on triangular emergency roadside warning devices to assess the effects of wind and traffic-induced gusts on their positional stability. These observations complement previous wind tunnel investigations.

A wind tunnel study was completed for the Aluminum Company of Canada into wind effects on a proposed aluminum digester plant to be erected in Ireland. The plant consists of three slender towers. Tower base bending moments and forces in ties between the towers were measured using a 1:39 scale aeroelastic model. The purpose of the ties is to suppress wind-induced motion.

In collaboration with the Division of Building Research an aerodynamic investigation of Commerce Court, Toronto is being undertaken. The purpose is to obtain wind tunnel comparisons with full scale measurements of surface pressures. A 1:200 scale model is now under construction for testing in the 30-ft. X 30-ft. wind tunnel. Preliminary wind simulation studies are now underway in the 3-ft. X 3-ft. wind tunnel.

A PDP11/34 minicomputer general purpose data acquisition and processing system is being constructed to simultaneously sample multiple analogue signals (at present up to 32) such as from strain gauges. These data can be acquired (up to 50,000 samples/sec) and processed rapidly in real time as the experiment progresses, and recorded on magnetic discs. An integral component is a hard-wired Fast Fourier Transform unit that can perform a 1000 point transform in less than 150 milliseconds.

FLUIDICS

Co-operative studies with D.G. Instruments of a 3-axis air velocity sensor are continuing using both NRC and industry developed concepts. Studies of vortex excitation of velocity sensor probes have been carried out in co-operation with FluiDynamic Devices Ltd. A program of applications of laminar flow in thin passages is being carried out in co-operation with the Control Systems and Human Engineering Laboratory of DME.

NUMERICAL METHODS

A correlational theory for the prediction of boundary layer transition has been devised and successfully demonstrated in some simple cases which are of interest for the design of airfoils.

The

The numerical methods are applicable to compressible flows involving heat and mass transfers at the boundaries.

VERTICAL AXIS WIND TURBINE

Dominion Aluminum Fabricating Ltd. has delivered six 15-ft. diameter wind turbines to NRC, who in turn has shipped these units to interested federal agencies for field trials. These units are now in operation. DAF are now marketing two sizes (a 15-ft. diameter (4kW) and a 20-ft. diameter (6dW) turbine). The 200 kW demonstration unit has been erected at the Magdalen Islands site and commissioning is underway.

AERIAL SPRAYING OF PESTICIDES

A co-operative program between NAE and the University of New Brunswick, to determine the droplet size distribution of standard nozzle configurations, is continuing. The experimental method consisted of photographing droplets in the 50- to 250-micron range using a narrow depth of focus, and a high intensity flash. An electronic detector was also placed in the spray; its function was to count the number of droplets in a given size range. The second stage of the experiment has been completed with measurements of droplet emissions from a Micronair rotary atomizer being made. Further wind tunnel testing will continue during the latter part of 1977.

A new spray boom designed has been tested in co-operation with Conair Aviation (Abbotsford, B.C.). This configuration will have significantly less aerodynamic drag than the present installation which is used on the DC-6B aircraft and is expected to save several hundred horsepower. The spray emission from the new configuration is currently being evaluated in flight.

Theoretical and experimental studies are continuing on the effects of the vortex wake and other factors on the swath width of spray left by a low flying aircraft.

LOW TEMPERATURE LABORATORY

RAILWAY CLIMATIC PROBLEMS

Under the auspices of the NRC Associate Committee on Railway Problems, Sub-Committee on Climatic Problems, a variety of analytical and experimental work is conducted on a continuing basis.

THERMAL PROTECTION OF TRACK SWITCHES

The use of heat to eliminate switch failures from snow and ice is a standard approach to this problem. Work has been carried out on improving the efficiency of forced convection combustion heaters and the means of distributing heat to the critical areas of a switch.

HORIZONTAL AIR CURTAIN SWITCH PROTECTOR

A non-thermal method of protecting a switch from failure due to snow has been undergoing development and evaluation. This method consists of high velocity horizontal air curtains designed to prevent the deposit of snow in critical areas of a switch. The tests conducted to date are especially encouraging with respect to yards and terminals. Additional evaluation is required for the line service application.

NEW RAILWAY SWITCH DEVELOPMENT

The ultimate solution to the existing problem of snow and ice failure of the point switch would appear to be replacement by a new design that is not subject to failure in this way. A switch has been designed, fabricated, laboratory tested and has now completed one winter season of field trials. The design involves only shear loading from snow and ice.

LOCOMOTIVE SANDING EQUIPMENT

An investigation into the various possible modes of failure of a locomotive sanding system resulting from low temperature has been undertaken. In addition to the expected failures resulting from moisture freezing in various parts of the pneumatic equipment, two other modes of failure are being investigated further.

HELICOPTER DE-ICING

A study of helicopter icing protection involving the evaluation of various systems (thermal, fluid, and self-shedding materials) and the development of de-icing control systems including ice detectors. The principles for a dynamic ice detector with high sensitivity to be used on helicopters are being investigated. Investigation of methods of establishing a rate function with the dynamic icing detection principle is being conducted.

MISCELLANEOUS ICING INVESTIGATIONS

Analytical and experimental investigations of a non-routine nature, and the investigation of certain aspects of icing simulation and measurement.

TRAWLER ICING

In collaboration with Department of Transport, an investigation of the icing of fishing trawlers and other vessels under conditions of freezing sea spray, and of methods of combatting the problem.

AIR CUSHION VEHICLE ENVIRONMENTAL PROBLEMS

A study has been started on the deposition of snow on sections representing possible tracks for guided ACV's. Snow and ice deposits are being measured and recorded during each winter storm.

A study of snow removal by unconventional methods is being undertaken for high speed transit systems.

AIRBORNE SNOW CONCENTRATION

To provide statistical data on the airborne mass concentration of falling snow in order to define suitable design and qualification criteria for flight through snow, measurements of concentration and related meteorological parameters are being made.

SEA ICE DYNAMICS

Analytical and experimental work on the techniques of forming low-strength ice from saline solutions is being carried out in connection with proposed modeling studies of icebreaking ships and arctic port facilities.

MARINE DYNAMICS AND SHIP LABORATORY

HIGH SPEED CRAFT

Several models in a systematic series have been studied and others are being prepared to determine their performance in still water and in waves.

YACHTS

A continuing program of sailing yacht model studies is underway using equipment and techniques developed in the laboratory.

BULK CARRIER

A model of a dry cargo vessel was constructed in the laboratory and an investigation made to determine the feasibility of its unique design. A new bow was made and fitted and additional studies carried out.

FOIL PROGRAM

An experiment program is to be conducted on a model of a hydrofoil main foil, for which program a special dynamometer has been built by the laboratory.

HYDROFOIL DESIGN SERIES

A series of five hydrofoil models is being considered and two have been built for investigation of their hull lift and drag, foil lift and drag seakeeping performance.

BEHAVIOUR OF SHIPS IN LOCKS

Three radio-controlled Great Lakes cargo vessel models with varying beams were built in the laboratory. A study of their behaviour is being carried out in a Seaway lock model in co-operation with the Hydraulics Laboratory. Investigation is being made of the hydrodynamic forces acting on the vessels during approach and passage through the locks with a view to recommending modifications to the existing lock structures and defining the effect of ship beam on entry and exit times. Some full-scale measurements have also been made on board a ship.

BULB/NOZZLE

A model of a bulb with a nozzle has been built in the laboratory and its effectiveness, independent of the ship's hull, has been analyzed. As a result of these studies a bulb/nozzle has been fitted to a bulk carrier model and evaluated.

Y-PASS SYSTEM

A model, equipped with a Y-Pass system, has been tested for resistance and propulsion and its performance evaluated.

DEVELOPMENT OF NON-AQUEOUS SOLUTION SYNTHETIC MODEL ICE

As is well known, the properties of full scale ice must be scaled down when carrying out model tests. To this end, extensive studies are being carried out of the physical characteristics and procedures for the manufacture of non-aqueous solution synthetic model ice for ship model experiments.

GREAT LAKES BULK CARRIER

A model of an 1100-ft. bulk acrrier is being constructed in the laboratory for resistance and propulsion studies.

DOUBLE-ENDED FERRY

A model of a double-ended, quadruple-screw ferry is being constructed in the laboratory for evaluation of its performance.

PATROL VESSEL

A model of a very high speed patrol vessel is being built in the laboratory for resistance experiments.

PATROL VESSEL

A model of a patrol vessel has been manufactured in fibreglass. It will be fitted with various stabilizers and extensive seakeeping experiments are to be carried out at various stabilizer configurations. A computer analysis will then assist in finding the optimum stabilizer configuration.

RAILWAY LABORATORY

RAILWAY STUDIES

Two experimental axles with spin controlled geometric properties have been manufactured and are being tested under a 100-ton grain car at the Uplands test centre. Trackside instrumentation has been developed.

The dynamometer car supplied by CP Rail for use as a mobile instrument car is being refurbished. The pocket to contain the coupler and draft gear is being modified.

The Laboratory continues to provide assistance to the Canadian Government in the assessment of the performance of passenger trains at high speed. An instrumented wheelset is being prepared for a reference vehicle. At the request of Ontario Northland Rail Services, recommendations were made on the running of the recently purchased Trans European Express over Canadian track. Tests were carried out.

RAILWAY DYNAMICS BUILDING (U-89)

The floor and control room have been completed. Rooms and services have been erected to house the electric power plant to the roller and vibration rigs. This complex includes a small workshop.

The vibration stands have been designed and the hydraulic power supply purchased for the building. Delivery of the actuators will be completed shortly. Design of the rail structure to support vehicles in the building has been completed. A sample stand has been manufactured.

Dynamometers have been connected to a pair of roller rig electric motors to aid in the development of their control. Initial testing is underway. A hybrid computer model has been developed in conjunction with the Analysis Laboratory.

Hardware for the roller rig is being developed and made by the Manufacturing Technology Centre. A design for the position controls has been carried out in the Railway Laboratory.

GENERAL INSTRUMENTATION

The laboratory is co-operating with the Marine Dynamics and Ship Laboratory in the development of the micro-processor controlled ship motion analyzer.

MECHANICAL AIDS TO THE HANDICAPPED

A pocketbook page turner has been developed; a Canadian manufacturer has made three and make ten more. Evaluation is continuing at two institutions.

NON-CONTACTING LEVEL GAUGE

Development of a non-contacting servo gauge using stepping motor drive for the measurement of tidal levels in hydraulic models.

MECHANICAL AIDS TO SURGERY

Continued technical support to two local hospitals in the use of prototype and commercial vessel suturing instruments for clinical surgery, and to their Departments of Experimental Surgery in organ transplant procedures, arterio-venous surgery, etc.

Assistance to Control Systems and Human Engineering Laboratory in the manufacturing of electrodes to improve the recording of electrospinograms.

NRC PERSONNEL APPLYING INSTRUMENTATION TO
TRANS EUROP EXPRESS TRAIN NOW KNOWN AS THE
NORTHLANDER.

STRUCTURES AND MATERIALS LABORATORY

FATIGUE OF METALS

Studies of the basic fatigue characteristics of materials under constant and variable amplitude loading; fatigue tests on components to obtain basic design data; fatigue tests on components for validation of design; studies of the statistics of fatigue failures; development of techniques to simulate service fatigue loading.

RESPONSE OF STRUCTURES TO HIGH INTENSITY NOISE

Study of excitation and structure response mechanisms; study of panel damping characteristics and critical response modes; investigation of fatigue damage laws; industrial hardware evaluation; investigation of jet exhaust noise.

OPERATIONAL LOADS AND LIFE OF AIRCRAFT STRUCTURES

Instrumentation of aircraft for the measurement of flight loads and accelerations; fatigue life monitoring and analysis of load and acceleration spectra; full-scale fatigue spectrum testing of airframes and components.

ELECTRON FRACTOGRAPHY

Qualitative determination of fracture mechanisms in service failures; fractographic studies of fatigue crack propagation rates and modes.

METALLIC MATERIALS

Structure-property relationships in cast and wrought nickel-base superalloys. Studies of the consolidation and TMT processing of superalloy powders and compacts by hot isostatic pressing, hot extrusion and upset forging; studies on mechanical properties. Mechanics of cold isostatic compaction of metal powders, properties of hydrostatically extruded solids and compacts, extruded at pressures up to 1600 MN/m^2. Studies of the oxidation/hot corrosion behaviour of coated and uncoated refractory metals and superalloys.

MECHANICS AND THEORY OF STRUCTURES

Stresses in multi-cell caissons for marine structures. Stress concentrations at corners of box structures. Behaviour of plates under high-speed impact, with reference to bird resistance of aircraft windshields.

FLIGHT IMPACT SIMULATOR

Simulator developed and calibrated to capability of accelerating a 4-lb. mass to velocity of 1000 ft./sec. and an 8-lb. mass to velocity of 760 ft./sec.; operation on year-round basis achieved and includes use of temperature controlled enclosure from −40° to +130°F; in addition to airworthiness certification program includes assessment of resistance to impact for materials and structural design for most types of viewing transparencies.

CALIBRATION OF FORCE AND VIBRATION MEASURING DEVICES

Facilities available for the calibration of government, university, and industrial equipment include deadweight force standards up to 100,000 lb., dynamic calibration of vibration pick-ups in the frequency range 10 Hz to 2000 Hz.

COMPOSITE MATERIALS

Studies of composites including resins, crosslinking compounds, polymerization initiators, selection of matrices and reinforcements, application and fabrication procedures, material properties, and structural design.

FINITE ELEMENT METHODS

Development and application of finite element methods to structural problems. Development of refined elements with curved edges. Development of methods for non-linear problems.

MOTOR VEHICLE SAFETY

The mathematical model of the redirection of a vehicle by a cable barrier has been validated experimentally and effort is now being concentrated on the development of a facility for the dynamic measurement of the inertial properties of automobiles by suspending them on air bearings. Engineering charts for the design of flexible road barriers are being prepared.

In collaboration with Ministry of Transport, Road and Motor Vehicle Traffic Safety Branch, studies to determine the performance of headlights in the driver passing task are being carried out. Work is continuing on a system for studying driver performance and traffic quality by the analysis of automatically recorded vehicle control input and response data.

POLICE EQUIPMENT STANDARDS

The NRC/CACP Technical Liaison Committee on Police Equipment is a bilateral arrangement for bringing together police and government personnel to review police equipment requirements, equipment performance specifications, and conformance testing procedures. Work of the Committee is expedited by a permanent Secretariat which has a primary responsibility for continuity in the activities of a number of Sections, each dealing with a particular area of expertise, and for co-ordinating work and specialist contributions from various participating Departments and organizations.

UNSTEADY AERODYNAMICS LABORATORY

DYNAMIC STABILITY OF AIRCRAFT

Development of new techniques for dynamic stability experiments.

Determination of cross-derivatives on an aircraft-like configuration at high angles of attack.

Exploratory measurements of vertical acceleration derivatives.

Development of an electro-mechanical calibrator for the existing dynamic cross-derivative apparatus.

ATMOSPHERIC DISTRIBUTION OF POLLUTANTS

Analysis of the downwind vertical spread of gaseous and aerosol pollutants from sources near the ground, with special emphasis on the effect of atmospheric stability.

Instrumentation of a small mobile laboratory to measure airborne particulates and of an aircraft to detect atmospheric tracers.

Use of the above detection system to measure the vertical spread of a pollutant in a polar atmosphere during the AES pilot study of polar meteorology on Lake Simcoe.

TRACE VAPOUR DETECTION

Development of highly sensitive gas chromatographic techniques for detection of trace quantities of vapours of pesticides, explosives and fluorocarbons.

Sensitivity evaluation of commercially available explosive detectors.

Airborne and ground-vehicle based measurements of the spread and distribution of various aerosols and tracer gases.

Development of techniques for conditioning and testing of biosensors.

WORK FOR OUTSIDE ORGANIZATIONS

Dynamic moment measurements and flow visualization studies for NASA, using wind tunnel facilities at NAE and at NASA Ames.

Feasibility and design studies for NASA.

Aircraft-security feasibility studies for Transport Canada.

Scientific assistance to interdepartmental Explosives Detector Evaluation Program, Montreal.

WESTERN LABORATORY (VANCOUVER)

PRACTICAL FRICTION AND WEAR STUDIES

In response to specific external request, various laboratory simulations of practical tribological situations to obtain friction and wear behaviour of lubricants and bearing materials. For example, one recent project involved determination of friction torque – temperature characteristics of marine steering helms as an aid in their manufacturing development.

FUNDAMENTAL STUDIES IN TRIBOLOGY

Continuing studies of friction and wear phenomena including preliminary investigations of abrasive wear of glassy carbons and other non-metallic solids.

LUBRICANT ANALYSIS

Analysis of used marine oils to assess their degree of deterioration as an aid to engine failure prevention.

PRACTICAL STUDIES OF BEARINGS AND SEALS

Design of a machine to test the effectiveness of the lubrication system of locomotive traction motor support (journal) bearings at low temperatures.

Construction of a static model of a vane in a ship's hydraulic steering gear to assess the effect of seal materials and design has been completed. Experimental work is now in progress.

INSTRUMENTATION STUDIES

A working prototype distributed light source and sensor has been constructed and successfully demonstrated for use in the automatic bus passenger system previously developed.

A high speed 'selector channel' is being adapted for use with the Western Laboratory mini-computer system.

Instrumentation has been developed for the Division of Building Research for the automatic tape recording of velocity and pressure measurements in snow avalanches in the Rogers Pass near the Trans-Canada Highway. This equipment was used over the past winter.

Further instrumentation to accommodate additional channels and a new 'geophone' trigger are presently under construction.

NUMERICALLY CONTROLLED MACHINING

Technical assistance on this subject is being provided to firms and other institutions in Western Canada which are considering the purchase of numerically controlled machines to improve their production efficiency. Seminars are held to explain the fundamentals of numerical control and programming and the laboratory's three-axis NC milling machine is used to machine demonstration batch quantities of typical components for interested companies.

Plans are being made to demonstrate the use of computer assisted programming and punched tape preparation as a means of reducing manual programming time for items requiring a large number of geometrical statements.

PUBLICATIONS

LABORATORY TECHNICAL REPORTS

National Aeronautical Establishment

LTR-FR-58 Daw, D.F.

Additional High Speed Icing Wind Tunnel Tests of Outside Air Temperature Probes for Use on NAE Cloud Physics Research Aircraft.
May 1977.

Division of Mechanical Engineering

LTR-CS-166 Gellie, R.W.

MBD Software Support.
April 1977.

LTR-CS-168 Gellie, R.W.

CAMAC Hardware Lists.
April 1977.

LTR-CS-173 Barnett, R.I., Romero-Sierra, C., Hamill, P.

High Resolution Densitometric Profiles of Human Chromosomes: Rationale and Analysis of a Complete Metaphase Spread.
May 1977.

LTR-FL-97 Dayson, C., Lowe, J.T.

The Friction and Wear of Some High Temperature Alloys and Composite Bearing Materials at 538°C (1000°F).
May 1977.

LTR-LT-74 Kimberley, H.J., Brierley, W.H.

Ice Removal from Concrete by High Pressure Water Jets.
April 1977.

MISCELLANEOUS PAPERS

Amyot, J.R., Gagne, R.E., Templin, R.J., Rangi, R.S. Magdalen Islands Wind Turbine Hybrid Computer Model. Proc. of the Summer Computer Simulation Conference, Chicago, Illinois, 18-20 July 1977.

Fowler, H.S. CASPAR ACV Research Project. Reprint No. 5. The Multicell Skirt with a Cell-Sealed Perimeter and Central Pressurized Cavity. Associate Committee on Air Cushion Technology, Technical Reprint, March 1977.

Gagne, R.E. Interactive Debug Package for Hybrid Computers. Proc. of Summer Computer Simulation Conference, Chicago, Illinois, 18-20 July 1977.

Langton, R., Evans, R.M., MacIsaac, B.D. Hybrid Computer Models as a Design Aid for Gas Turbine Control System for Helicopters. Proceedings of the Summer Computer Simulation Conference, Chicago, Illinois, 18-20 July 1977.

MacPherson, J.I., Isaac, G.A. Turbulent Characteristics of Some Canadian Cumulus Clouds. J. Applied Meteorology, Vol. 10, No. 1, January 1977, pp. 81-90.

Markham, P. de L. The Probe and Other Developments in Explosives Detection in Canada. Presented at the Third International Conference on Terrorist Devices and Activities, Deepcut, Surrey, England, 9-13 May 1977. Published in the Proceedings. (Restricted, Title Unclassified.)

MISCELLANEOUS PAPERS (Cont'd)

Mokry, M. Assessment of Wall Interference Effects in the NAE 5-ft × 5-ft Wind Tunnel by Use of the ONERA Calibration Models. Presented at the 47th semi-annual STA meeting at Hawthorne, California on April 7-8, 1977.

Orlik-Rückemann, K.J. Dynamic Stability Testing in Wind Tunnels. Lectures given at a Lecture Series on Aerodynamic Inputs for Problems in Aircraft Dynamics at the von Karman Institute for Fluid Dynamics, Rhode-Saint-Genèse, Belgium, 25-29 April 1977. Published in Lecture Notes, Lecture Series 99.

Peake, D.J., Bowker, A.J., Lockyear, S.J., Ellis, F.A. Non-obtrusive Detection of Transition Region Using an Infra-Red Camera. Presented by D.J. Peake at the AGARD FDP Symposium on 'Laminar Turbulent Transition' at Copenhagen, Denmark on May 2-4, 1977.

Rudnitski, D.M., MacIsaac, B.D. Reduction of Transient Gas Turbine Test Data Using a Hybrid Computer. Proc. of Summer Computer Simulation Conference, Chicago, Illinois, 18-20 July 1977.

Sinclair, S.R.M., Roderick, W.E.B., Lum, K. The NAE Airborne V/STOL Simulator. Presented at AGARD FMP Symposium on Rotorcraft Design, NASA Ames Research Center, Moffett Field, California, May 16-19, 1977.

UNPUBLISHED PAPERS

Anstey, C. Flow Fluctuation Measurement in the NAE 30 × 16 in. Wind Tunnel. Presented at the 47th Meeting of the Supersonic Tunnel Association, Hawthorne, California, 7-8 April 1977.

Anstey, C. Improved Servo Valve for a High-Load Hydraulic Drive. March 1977.

Ayad, A.A. The Relevance of Pavement Reflectance Measurements to the Nigh Visibility Problem. Paper presented at the ARTAC Annual Meeting, May 10, 1977, at Reyerson Institute in Toronto.

Buck, L. Ergonomic Considerations in the Design of Displays. Paper read at I.S.A. Symposium on Human Engineering Aspects of Process Control, Edmonton, Alberta, 20 April 1977.

Crabtree, D. Spinal Cord Integrity Monitoring. Presented at a meeting of the Clinical Engineering Physics Association, 17 June 1977, N.R.C.

Fowler, H.S. The State of ACV Development in Canada. Lecture given as part of short course on Advanced Marine Vehicles, University of Virginia, 6-10 June 1977.

Irwin, H.P.A.H. Aeroelastic Instability of Suspension Bridges. Princeton University, Princeton, N.J., U.S.A., 3 May 1977.

Irwin, H.P.A.H. Aerodynamic Investigations of Lions' Gate Bridges. The University of Western Ontario, London, Ontario, 15 April 1977.

Markham, P. de L. Jettison of Suspected Improvised Explosive Devices from Aircraft. (Restricted, Title Unclassified.) March 1977.

Orlik-Rückemann, K.J. On Dynamic Stability of Modern Military Aircraft – New Problems and Recent Results. Seminar presented at the Aeronautical Research Institute (FFA), Stockholm, Sweden, 25 May 1977.

Ringer, T.R. Transportation in a Cold Climate. Presented at a seminar on transportation for the Ontario Teachers Federation at N.R.C., Ottawa, on May 11, 1977.

Stallabrass, J.R. Measurements of the Concentration of Falling Snow. Presented to the Eleventh Annual Congress of the Canadian Meteorological Society, June 1, 2 & 3, 1977, Winnipeg, Man.

Tanner, J.A. Interdisciplinary Research at the N.R.C. – An Introduction. Talk given to Interdisciplinary Science Studies Workshop, Ontario Teachers' Federation, Ottawa, 10 May 1977.

Templin, R.J. Wind Energy. Presented at the Third Canadian National Energy Forum, April 4-5, 1977, Halifax, Nova Scotia.